DISAPPEARING POLAR BEARS AND PERMAFROST: IS A GLOBAL WARMING TIPPING POINT EMBEDDED IN THE ICE?

HEARING

BEFORE THE

SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

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C O N T E N T S

October 17, 2007

DISAPPEARING POLAR BEARS AND PERMAFROST: IS A GLOBAL WARMING TIPPING POINT EMBEDDED IN THE ICE?

WEDNESDAY, OCTOBER 17, 2007

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:05 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Brad Miller [Chairman of the Subcommittee] presiding.

BART GORDON, TENNESSEE
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Subcommittee on Investigations and Oversight

Hearing on:

Disappearing Polar Bears and Permafrost: Is a Global Warming Tipping Point Embedded in the Ice?

2318 Rayburn House Office Building
Wednesday, October 17, 2007
10:00 a.m. – 12:00 p.m.

Witnesses

Dr. Richard Alley
Evan Pugh Professor of Geosciences, Department of Geosciences, Pennsylvania State University

Dr. Glenn Juday
Professor, School of Natural Resources and Agricultural Sciences, University of Alaska at Fairbanks

Dr. Sue Haseltine
Associate Director for Biology, U.S. Geological Survey, U.S. Department of Interior

Ms. Kassie R. Siegel
Director, Climate, Air and Energy Program, Center for Biological Diversity

HEARING CHARTER

SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

Disappearing Polar Bears and Permafrost: Is a Global Warming Tipping Point Embedded in the Ice?

WEDNESDAY, OCTOBER 17, 2007
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose:

On Wednesday, October 17, 2007, the Investigations and Oversight Subcommittee will hold a hearing on the impacts of global warming on the Arctic. This hearing will provide the Committee with an opportunity to hear from witnesses on three interrelated matters: (1) the current situation in the Arctic, including the situation facing the polar bear, (2) ways in which warming in the Arctic may accelerate global warming, especially through the emission of more greenhouse gases, and (3) interim steps that could be taken to reduce greenhouse gas emissions while the Congress weighs more elaborate carbon trade or tax proposals.

One of the themes that should emerge from this hearing is that, from a layman's perspective, the models used to project climate change and its ramifications appear to be conservative in their projections. This is because any phenomena that are not understood well enough to be represented in models with confidence are excluded. These other phenomena may accentuate or depress warming trends. In the case of the Arctic, most of the phenomena that have been excluded from the models are believed to accentuate warming and its effects. Few will depress it. The modeling on polar bear survival, for example, uses projections from the IPCC models to estimate future changes in sea ice extent. Since the bears' condition is very dependent upon both the extent of the sea ice and the duration of ice-free periods, projections of the bear survival are very dependent upon projections of sea ice. This summer the sea ice extent is far less than projected by the models.

Some important factors that induce additional warming are either left out of IPCC models or are not fully accounted for, and therefore the actual decrease in sea ice extent could be significantly greater than the IPCC projections. For example, the IPCC modeling fails to include positive feedbacks from permafrost thawing which could add millions—even billions—of metric tons of greenhouse gases to the environment. Projections of sea level rise in the IPCC exercise do not include any run-off from melting ice sheets in Greenland or Antarctica because the physical dynamics of that process are so poorly understood. The result is that, as disturbing as the polar bear study is or as worrisome as the IPCC reports are, they probably minimize the global warming path we are on and the consequences we will live through as a result of that warming.

Recent Global Warming Reports Related to the Arctic

The past twelve months have seen two remarkable stories related to the Arctic. In January of 2007, the Department of the Interior proposed to list the Polar Bear as an endangered species. This proposal came in response to a successful lawsuit brought by the Center for Biological Diversity, which charged that the decline in the bear's habitat—a direct consequence of global warming—justified a listing. Subsequent information developed by the U.S. Geological Survey (USGS) provides ample reason to believe that the bear will disappear entirely from large areas of its range in the next fifty years, and will be on the verge of extinction by 2100.

Diminishing ice cover is directly tied to the survival of the polar bear. Bears rely on ice from which to hunt seals—their main prey. The analysis done by the USGS projects that in three of the four ice eco-regions of the Arctic, it is most likely that the bears will be eliminated by 2100. In the fourth region, the modeling projects almost even odds that the bears will be somewhere between retaining a small population to being extinct, but it appears that even a small population may not be enough for sustaining the species beyond 2100.

The disturbing quality of the USGS analysis is that their models were derived from statistical projections that have not predicted as steep a decline of actual ice loss as has occurred in the Arctic. In other words, the modeling of polar bear populations assumes more ice extent than the real world is actually producing. Further, there was no accommodation to the modeling made for the consequences of other environmental factors that may occur if the world begins to extract more resources from the Arctic and if a Northwest Passage becomes a reliable shipping route. Such activities would have a further negative effect on a remaining polar bear population.

The second event that has received widespread attention has been the report that the melt of Arctic sea ice set a record for a new summer minimum. The National Snow and Ice Data Center (NSIDC) announced on October 1 that the "Arctic sea ice during the 2007 melt season plummeted to the lowest levels since satellite measurements began in 1979." The NSIDC lead scientist, Mark Serreze, commented that "The sea ice cover is in a downward spiral and may have passed the point of no return. As the years go by, we are losing more and more ice in summer and growing back less and less ice in winter. We may well see an ice-free Arctic Ocean in our lifetimes. The implications for global climate, as well as Arctic animals and people, are disturbing." There has not been an ice-free summer in the Arctic in one million years.

Diminishing bears and sea ice are only the most widely reported aspects of a warming Arctic. Global climate scientists worry about "tipping points"—environmental processes that could lead to rapid and irreversible changes in the overall global climate or in sea level rise. The Arctic contains several potential sources of a tipping point in the boreal forests, the albedo effects of melting ice and, one of the most worrisome, permafrost.

Tipping Points in the North

The Arctic permafrost acts as a kind of frozen locker in which carbon is stored. These frozen soils, as well as frozen peat, extend over large areas of North America and Siberia—perhaps as much as 80 percent of the area. Much of the infrastructure of Russia, Alaska, and the Canadian North is built on permafrost. With thawing of permafrost, some of which extends more than 100 feet in depth, subsidence occurs; peoples' homes, roads, and pipes all could be damaged or destroyed. As disturbing as these consequences are, from a global perspective there is a more profound result: thawing permafrost release stored carbon as either carbon dioxide or as methane.

Estimates of the total stored carbon in Arctic soils are in the range of one thousand gigatons. (See Zimov, Schuur, Chapin III, "Permafrost and the Global Carbon Budget," *Science Magazine,* Vol. 312, 16 June, 2006). No one knows how much is currently being released, though there are anecdotal reports of methane emerging so quickly from pools in Siberia that it keeps ice from freezing in the dead of winter. The Stordalen mire in Sweden has been observed to produce a 22–66 percent increase in methane emission as the permafrost thawed. (Christensen, et. al., "Thawing sub-arctic permafrost: Effects on vegetation and methane emissions," *Geophysical Research Letters,* V. 31, L04501, 2004).

Work done at the National Center for Atmospheric Research (NCAR) projects that over half of the topmost layer of permafrost (top ten feet) will have thawed by 2050 and as much as ninety percent could thaw by 2100. The analysts worked on this question with an eye to modeling increased water runoff from the permafrost into the Arctic Ocean. Their model did not tackle the question of carbon emissions from thawing permafrost, but they conceded that such releases "may be considerable and the feedback is likely to be positive and possibly large." (Lawrence & Slater, "A Projection of Severe Near-Surface Permafrost Degradation During the 21st Century," *Geophysical Research Letters,* V. 32, L24401, 2005).

While scientists know that thawing permafrost and the release of carbon stored in its frozen matrix could have an enormous impact on overall greenhouse gas emissions, none of the modeling done for the IPCC takes this feedback mechanism into consideration. Past and present anthropogenic emissions of greenhouse gases may so warm the planet that aggressive efforts over the next thirty years to reduce anthropogenic emissions may not be enough to stop the thawing of permafrost and the release of the enormous stores of carbon in those soils.

Permafrost is not the only potential source of accelerated warming. Another potential source for carbon releases lies in the boreal forests of the North. The region is warming and large areas of North America's Arctic have been subjected to drought. The warmer weather has made the region more hospitable to insects that have attacked the massive conifer boreal forests. In the Province of British Columbia, Canada, pine beetles have become an "epidemic." As of 2006, the beetles had destroyed $6 billion worth of trees and the provincial government began pushing a massive logging increase to try to get ahead of the insect-driven losses. It is estimated that B.C. alone contains almost seven percent of the world's softwood. As a researcher at the Pacific Forestry Centre in Victoria, Allan Carroll, puts it, "There's no question [the pine beetles] range has expanded over the last 30 years due to ameliorating climate. . ." (Webster & Cathro, "Bitter Harvest: Pine Beetle Infestation in B.C.," *Canadian Business,* January 2006).

Insect-weakened, dry trees are subject to fire. This past summer saw the largest forest fire ever witnessed on Alaska's North slope. On July 16, 2007 lightning started a fire that was still burning in the first week of October. It had consumed more than a quarter of a million acres of forest during its run, and the smoke plume could be seen from 50 miles away. Scientists in Alaska are concerned that the fire may have damaged the permafrost beneath the forest, causing deeper thaw. As these trees burn, and others succumb to drought and insects, carbon is released into the atmosphere. The loss of trees to store carbon and the release of carbon from dying forests is a potentially important source of greenhouse gases. (Hopkin, "Alaskan Fire Damages Permafrost," *Nature,* published online 9 October 2007).

Finally, the change in albedo in the North could have an important impact on overall global temperature. As snow and ice melt, they reveal the darker Earth and ocean. The overall color of the planet's surface directly affects how much solar energy is absorbed by the planet and how much is reflected back out into space. Being darker, the sea will absorb more solar energy, warming the seas and accelerating the melting of the ice. A similar process happens on land that would traditionally be covered by snow. (Note that the loss of boreal forests may have a small negative feedback by revealing a lighter ground under the dark trees—thus reflecting marginally more solar energy back into space than the forests).

Any of these processes that either cause the Earth to absorb or retain more solar radiation will add to the overall warming of our atmosphere. If the atmosphere warms enough to reach a tipping point on the ice sheets of Greenland or Antarctica, the consequences for coastal communities and the world economy would be devastating. Scientists do not fully understand the dynamics of ice sheet melting, but it is not a simple linear process where a certain temperature produces a certain rate of melt. Rather there are feedbacks in the melting of the sheets that suggests an exponential or accelerating reaction occurs when melting begins. If the ice sheets of Greenland and Antarctica were to both melt, it would increase the sea level by approximately 200 feet. Experts believe that such an event is extremely unlikely. As one of our witnesses will testify, it is expected that increases in sea level will not occur so rapidly as to raise sea level at the rate of meters over coming decades. However, because the physical dynamics of ice sheet melting are not well understood, they were simply left out of the IPCC's most recent projections of sea level rise in the 21st Century. We currently have no reliable, comprehensive projection of sea level rise due to this gap in our understanding of ice sheet dynamics in conditions of warming.

A Modest Proposal for Action

The Center for Biological Diversity will appear to provide some advice on steps that can be taken to reduce warming, with particular emphasis on their efficacy in the Arctic. Among the steps they advocate are programs to reduce methane emissions and "black carbon." Black carbon is soot that, in the Arctic, has a particularly pernicious effect. When it is deposited on snow and ice it decreases its reflectivity and increases its heat absorption leading to greater melting. As the Arctic comes under more and more industrialization with other warming, one could anticipate further production of black carbon. Methane is a powerful greenhouse gas, with an estimated global warming potential 23 times greater than carbon dioxide over a 100-year time frame. Methane is a precursor to tropospheric ozone. In that form, it traps shortwave radiation as it enters the Earth's atmosphere from the sun and then when it is reflected back again by snow and ice. As a consequence, its impact is strongest over the Poles. Reducing global methane emissions would provide a particular benefit to the Arctic.

Witnesses

Dr. Sue Haseltine is the Associate Director for Biology at the U.S. Geological Survey, U.S. Department of Interior and will make a presentation of their findings regarding the future of the polar bear.

Ms. Kassie R. Siegel is the Director of the Climate, Air and Energy Program at the Center for Biological Diversity. She will present their preliminary plan for the mitigation of methane emissions.

Dr. Richard Alley, Evan Pugh Professor of Geosciences at Pennsylvania State University, appeared before the Committee to testify about the findings of the IPCC report earlier this year. He will testify about matters including sea ice, albedo and ice sheet melting. He can also answer questions regarding what factors have and have not been included in IPCC modeling on the climate.

Dr. Glenn Juday is a Professor at the School of Natural Resources and Agricultural Sciences, University of Alaska at Fairbanks, one of the worlds leading centers for the study of the Arctic. He will testify regarding both permafrost—what we do and do not understand about its potential release of carbon—and the boreal forests.

Chairman MILLER. Good morning. The hearing will come to order. Today's hearing is entitled *Disappearing Polar Bears and Permafrost: Is a Global Warming Tipping Point Embedded in the Ice?*

This committee held three hearings on the 2007 report of the Intergovernmental Panel on Climate Change, IPCC, one of last week's winners of the Nobel Prize for Peace. The report of the working group on impact, adaptation, and vulnerability stated that the rapid climate changes occurring in the Earth's polar regions would have cascading effects on key regional bio-physical systems and cause global climatic feedbacks.

The report described the polar regions as geopolitically and economically important and extremely vulnerable to current and projected climate change. And the report said the polar regions had the greatest potential to affect global climate change and thus human populations and biodiversity.

In the past twelve months, there have been two remarkable stories related to the Arctic that suggest that those climate changes may be happening even faster than predicted and with significant negative consequences. Earlier this month, the National Snow and Ice Data Center at the University of Colorado reported that the Arctic sea ice cover in the summer of 2007 had fallen to its lowest point since 1979. Sea ice coverage was 39 percent below the long-term average for 1979 to 2000 and perhaps half the sea ice coverage of the 1950s.

According to the Center, Arctic sea ice has long been recognized as a sensitive climate indicator. When global temperatures rise, the sea ice cover sinks, and global temperatures in the Arctic have risen four degrees Fahrenheit since 1950. The lead scientist for the Snow and Ice Center warned that the sea ice cover is in a downward spiral and may have passed the point of no return. As the summers go by, we are losing more and more ice in the summer and growing less and less back in the winter. We may well see an ice-free Arctic Ocean in our lifetimes. The implications for global climate, as well as Arctic animals and people, are disturbing.

There has not been an ice-free summer in the Arctic in a million years.

Not surprisingly, the U.S. Geological Survey in September issued a report projecting that, based on the projected sea ice melts, two-thirds of the world's polar bears will be gone by 2050. The USGS study projects that in three of the four ice eco-regions of the Arctic, it is most likely that the bears will be extinct by 2010. In the fourth region, the modeling projects almost even odds that the bears will be somewhere between having a small population to being extinct, but a small population may not be enough to sustain the species.

Polar bears are adapted to hunting from sea ice. They hunt primarily ringed seals and to a lesser degree bearded seals. Less sea ice means less habitat. The USGS analysis relied on models to project polar bear populations that are more conservative about the melting of sea ice than the steeper decline that is now being observed in the Arctic. Polar bears are adapted to hunting from sea ice.

Diminishing bears and sea ice are only the most widely reported aspects of a warming Arctic. Global climate scientists worry about tipping points, atmospheric processes that could lead to a rapid and irreversible change in the overall global climate or in sea level rise. The Arctic contains several potential sources of a tipping point in the boreal forests, the albedo effect of melting ice and one of the most frightening, carbon and methane release from melting permafrost.

Again, the polar regions, the Arctic and the Antarctic, have the greatest potential of any region to affect global climate everywhere. The impacts of global warming will be greater in the polar regions, and those impacts will also produce feedback effects that have globally significant consequences. First, ice and snow reflect solar radiation in a process known as albedo. It helps keep the Arctic cool and the Earth cooler. When there is less ice and less snow, the exposed soil and water absorb solar radiation instead of reflecting it; and more solar radiation and warmth reaches land and stays in the atmosphere. It becomes a cycle. Ice melts and snow cover is reduced, resulting in less reflectivity and more warming, resulting in more ice melting and reduction of snow cover and on and on.

Second, because of higher temperatures in the Arctic, the permafrost beneath large sections of Europe, Russia, Alaska and Canada is also beginning to melt. There are estimated to be almost 1,000 gigatons of carbon trapped in Arctic permafrost. A gigaton is a billion tons. Human use of fossil fuels currently emits approximately seven gigatons of carbon annually. In 2005, scientists at the Snow and Ice project projected 50 percent decrease of the topmost layer of permafrost by 2050 and as much as a 90 percent decrease by 2100. If that happens, the resulting release of CO_2, carbon dioxide, and methane could have a warming effect on our climate that defies imagination.

Another potential source for carbon release rests in the boreal forests of the North. Warmer weather has made them vulnerable to insect pests, and drought has resulted in the largest forest fire ever witnessed on Alaska's Northern Slope. It may also have damaged the permafrost.

None of the models used in the IPCC projections of the impact of global warming took into account the potential release of those gigatons of carbon. A vast area of the world that has been a net carbon sink could become a carbon dioxide and methane producer that would dwarf the production of carbon dioxide and methane now resulting from human activities. As Dr. Ted Schuur wrote in Science magazine, factors inducing high-latitude climate warming should be mitigated to minimize the risk of a potentially large carbon release that would further increase global warming.

Rapid Arctic ice and permafrost melt are the kind of events with cascading effects that tip the planet's climate into an uncontrollable cycle of warming. The result could be an acceleration of the melting of the ice sheets in Greenland, inundating coastal communities and devastating the world economy.

For 20 years we have heard warnings from scientists, first in a hearing here held by Mr. Gore, an alumnus of this committee.

Now we are seeing the consequences of global warming in the endangering of polar bears, in the eroding infrastructure of the Arctic and in melting sea ice.

Dr. James Hansen of NASA said a year ago that we have 10 years to act. If he is right, we have nine years left to put this country and the world on a path to reducing aggressively our carbon emissions. We certainly can do that and probably at a relatively modest cost if we have the will.

Some dismiss the threat of global warming as gloom and doom, and proclaim themselves to be sunny optimists who believe things will turn out all right. Willfully ignoring dangers and turning a blind eye to all evidence that there is a problem that needs our urgent attention is not optimism, it is folly. It is optimism to believe that we will prove equal to the challenges before us, however daunting; and I am optimistic in that respect, but we better get about it.

[The prepared statement of Chairman Miller follows:]

PREPARED STATEMENT OF CHAIRMAN BRAD MILLER

This committee held three hearings on the 2007 report of the Intergovernmental Panel on Climate Change (IPCC), one of last week's winners of the Nobel Prize for Peace. The report of the working group on impact, adaptation and vulnerability stated that the rapid climate changes occurring in the Earth's polar regions would have "cascading effects on key regional bio-physical systems and cause global climatic feedbacks." ("Climate Change 2007: Impacts, Adaptation and Vulnerability," Chapter 15, p. 655, *Fourth Assessment Report of the IPCC.*) The report described the polar regions as geopolitically and economically important and extremely vulnerable to current and projected climate change. And the report said the polar regions had the greatest potential to affect global climate change and thus human populations and biodiversity. *Id.*

In the past twelve months, there have been two remarkable stories related to the Arctic that suggest that those climate changes may be happening even faster than predicted and with significant negative consequences. Earlier this month, the National Snow and Ice Data Center at the University of Colorado reported that the Arctic sea ice cover in the summer of 2007 had fallen to its lowest point since 1979. Sea ice coverage was **39 percent** below the long-term average from 1979 to 2000, and perhaps half the sea ice coverage of the 1950s.

According to the Center, Arctic sea ice has long been recognized as a sensitive climate indicator. When global temperatures rise, the sea ice cover shrinks. And global temperatures in the Arctic have risen four degrees Fahrenheit since 1950. The lead scientist for the Snow and Ice Center warned that, "The sea ice cover is in a downward spiral and may have passed the point of no return. As the years go by, we are losing more and more ice in summer and growing back less and less ice in winter. We may well see an ice-free Arctic Ocean in our lifetimes. The implications for global climate, as well as Arctic animals and people, are disturbing."

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Polar bears are adapted to hunting from sea ice. They hunt primarily ringed seals and, to a lesser degree, bearded seals. Less sea ice means less habitat. The USGS analysis relied on models to project polar bear populations that are more conservative about the melting of sea ice than the steeper decline being observed in the Arctic. Further, the modeling did not consider the consequences of permafrost melt and other environmental influences that would apply if the world begins to extract more resources from the Arctic, and if a Northwest Passage becomes a reliable shipping route. Those activities would have an obvious negative effect on any remaining polar bear population.

Diminishing bears and sea ice are only the most widely reported aspects of a warming Arctic. Global climate scientists worry about "tipping points"—atmospheric processes that could lead to rapid and irreversible changes in the overall global climate or in sea level rise. The Arctic contains several potential sources of a tipping point in the boreal forests, the albedo effects of melting ice and—one of the most frightening—carbon and methane release from melting permafrost.

Again, the polar regions—the Arctic and the Antarctic—have the greatest potential of any region to affect global climate everywhere. The impacts of global warming will be greater in the polar region, and those impacts will also produce feedback effects that have globally significant consequences. First, ice and snow reflect solar radiation in a process known as "albedo." It helps keep the Arctic cold and the Earth cooler. When there is less ice and less snow, exposed soil and water absorb solar radiation instead of reflecting it, and more solar radiation and warmth reaches land and stays in the atmosphere. It's a cycle: Ice melts and snow cover is reduced, resulting in less reflectivity and more warming, resulting in more ice melting and reduction of snow cover.

Second, because of higher temperatures in the Arctic, the permafrost beneath large sections of Europe, Russia, Alaska and Canada is also beginning to melt. There are estimated to be almost 1,000 gigatons of carbon trapped in the Arctic permafrost. A gigaton is a billion tons. Human use of fossil fuels currently emits approximately seven gigatons of carbon annually. In 2005, scientists at the Snow and Ice Data Center projected 50 percent of the topmost layer of permafrost would melt by 2050 and as much as 90 percent by 2100. If that happens, the resulting releases of CO_2 and methane could have a warming effect on our climate that defies imagination. Another potential source for carbon release rests in the boreal forests of the North. Warmer weather has made them vulnerable to insect pests, and drought has resulted in the largest forest fire ever witnessed on Alaska's Northern Slope. It may also have damaged the permafrost.

None of the models used in the IPCC projections of the impact of global warming took into account the potential release of these gigatons of carbon. A vast area of the world that has been a net carbon sink could become a carbon dioxide and methane producer that would dwarf the production of carbon dioxide and methane now resulting from human activities. As Dr. Ted Schuur wrote in *Science* magazine in June of 2006, "Factors inducing high-latitude climate warming should be mitigated to minimize the risk of a potentially large carbon release that would further increase global warming."

Rapid Arctic ice and permafrost melt are the kind of events with "cascading effects" that tip the planet's climate into an uncontrollable cycle of warming. The result could be an acceleration of the melting of the ice sheets in Greenland, inundating coastal communities and the devastating the world economy.

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Dr. James Hansen of NASA said a year ago that we have ten years to act. If he is right, we have nine years left to put this country, and the world, on a path to reducing aggressively our carbon emissions. We certainly can do it, and probably at a relatively modest cost, if we have the will.

Some dismiss the threat of global warming as gloom and doom, and proclaim themselves to be sunny optimists who believe things will turn out all right. Willfully ignoring dangers and turning a blind eye to all evidence that there are problems that need our urgent attention is not optimism, it is folly. It is optimism to believe that we can prove equal to the challenges before us, however daunting. But we better get about it.

Chairman MILLER. The Chair now recognizes Mr. Sensenbrenner, for an opening statement.

Mr. SENSENBRENNER. Thank you very much, Mr. Chairman. Today's hearing takes a wide breadth, from predicted declines in polar bear populations, to whether polar bears should be listed under the *Endangered Species Act,* to melting permafrost and its implications to the ecological affect of climate change on spruce tree populations. Individual topics are too complex to approach in depth in a single hearing, but the common thread is obviously climate change and the underlying truth that the Arctic is melting.

There is obvious value in bringing the world's attention to the problem, but we may have reached a tipping point when it comes to raising awareness on climate change. We have the world's attention; the question now is what we're going to do about it. As the diverse subject matter of today's hearing suggests, climate change can have broad effects that we are only beginning to understand; but as I have continuously maintained, solutions to climate change are no less complex than the consequences. Our approach to combating climate change cannot be shortsighted. We need to reduce our greenhouse emissions, but we cannot do so in a way that jeopardizes our ability to meet our energy demands or cripples our economy. Our energy demands are rising, and running out of conventional power plants is a real threat. We need to find solutions like nuclear power that limit carbon emissions but also ensure that our energy needs will be met.

We're also facing unprecedented economic challenges. As the challenges of competing in the global economy grow, rapidly developing countries like China and India have made it clear that they will not hinder their economic growth to curb climate change. I heard that repeatedly in Kyoto and Buenos Aires and in the Netherlands. This means that any modest success that we enjoy at limiting our emissions will be completely offset by China and other nations. We cannot afford to stall our own economic development when other nations will not be similarly handicapped.

Today's hearing, like the hearing we had last month, is focused on dire predictions relating to climate change. These concerns are important, but we could just as easily be focused on dire predictions about our ability to meet energy demands or to meet the growing economic challenges of globalization. These three challenges are deeply intertwined, and our solution to them needs to be comprehensive and address all of them.

USGS's most recent report on polar bears and sea ice is in some ways encouraging. While the report indicates that both sea ice and polar bear populations will decline over coming decades, the report does conclude that there will still be a viable polar bear population even a century from now. It is also encouraging that many of the problems we are facing, from the national security implications we discussed last month to the polar bears, sea ice, permafrost, and spruce trees we are here to discuss today; they are all symptoms of the same underlying problem. As we develop and implement technologies for alternative energies, we reduce the threat from all of these symptoms, and I am confident that we can reduce these threats with a comprehensive approach that meets our energy needs and strengthens our economy.

I yield back the balance of my time.

[The prepared statement of Mr. Sensenbrenner follows:]

PREPARED STATEMENT OF REPRESENTATIVE F. JAMES SENSENBRENNER, JR.

Today's hearing takes a wide breadth—from predicted declines in polar bear populations, to whether polar bears should be listed under the *Endangered Species Act,* to melting permafrost and its implications, to the ecological affects of climate change on spruce tree populations. The individual topics are too complex to approach in depth in a single hearing, but the common thread is obviously climate change and the underlying truth that the arctic is melting.

There is obvious value in bringing the world's attention to the problem, but we may have reached a tipping point when it comes to raising awareness on climate change—we have the world's attention, the question now is what we are going to do with it. As the diverse subject matter of today's hearing suggests, climate change can have broad effects that we are only beginning to understand.

But as I have continuously maintained, solutions to climate change are no less complex than the consequences. Our approach to combating climate change can not be short-sighted. We need to reduce our greenhouse emissions, but we can not do so in a way that jeopardizes our ability to meet our energy demands or cripples our economy. Our energy demands are rising and running out of conventional power plants is a real threat. We need to find solutions, like nuclear power, that limit carbon emissions, but also ensure that our energy needs will be met.

We are also facing unprecedented economic challenges. As the challenges of competing in a global economy grow, rapidly developing countries like China and India have made clear that they will not hinder their economic growth to curb climate change. This means that any modest successes that we enjoy at limiting our emissions will be completely offset by China and other nations. We cannot afford to stall our own economic development when other nations will not be similarly handicapped.

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Chairman MILLER. Thank you, Mr. Sensenbrenner. If there are other Members who wish to submit additional opening statements, your statements will be added to the record at this point.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Mr. Chairman, I appreciate the Subcommittee addressing this issue today and continuing an emphasis on matters affecting our environment. The melting of the ice sheets and permafrost and the deterioration of the boreal forests all have potentially severe consequences for the Earth and scientific estimates of global climate change.

A central question we must address is how do we prepare for these possible effects when the processes can be hard to track and the physical properties in question are not always well understood? This becomes very important when you consider that models to date have been too conservative, predicting less melt than has actually occurred.

Loss of ice cover also is predicted to have a disastrous effect on the polar bear population over the next century. I look forward to hearing more about the consequences of ice melt and how to deal with the uncertainty of some of these projections.

Mr. Chairman, I again commend you for calling this hearing so we can have a better understanding of these issues. In an era of scarce government resources, we must choose wisely how we prioritize issues and create public policy, and this topic certainly can inform how we view the debate on global climate change.

Chairman MILLER. And now, I would like to introduce our witnesses. Dr. Richard Alley is the Evan Pugh Professor of Geosciences at Pennsylvania State University. Dr. Alley appeared before the Committee to testify about the findings of the IPCC Report earlier this year. Today he will testify about matters including sea ice, the impact of albedo and ice sheet melting. Dr. Glenn Juday is a Professor of the School of Natural Resources and Agricultural

Sciences at the University of Alaska at Fairbanks, one of the world's leading centers for the study of the Arctic. He will discuss recent climatic changes in Alaska including those in the permafrost and what we do and do not understand about the potential release of carbon in the boreal forest. Dr. Sue Haseltine is the Associate Director of Biology at the U.S. Geological Survey. She will discuss the findings in its study on the population projections of the polar bears for the next century. Ms. Kassie Siegel is the Director at Climate, Air, and Energy Program at the Center for Biological Diversity. The Center initiated a lawsuit under the *Endangered Species Act* that resulted in the proposed listing of the polar bear as an endangered species and resulted in the USGS study. She will discuss the Center's proposed rapid-action plan to address Arctic meltdown and to save the polar bear.

As our witnesses should know, your full written statement will be placed in the record; and your oral testimony is limited to five minutes each. We will give you a little forgiveness on that, but try to pay attention when you see the red light come on. It is also the practice of the Subcommittee to take testimony under oath. Do any of you have any objection to being sworn in? I have to say it seems unlikely to me that any testimony at this hearing would result in perjury charges, but we do want to put you under oath. Just relax at that prospect. And to relax you further, we also always ask if you are represented by counsel today. You are entitled to be represented by counsel. Do any of you have counsel today? You are all on your own? Okay.

If you would now please stand and raise your right hand?

[Witnesses sworn]

Chairman MILLER. Dr. Alley, you may begin.

STATEMENT OF DR. RICHARD B. ALLEY, EVAN PUGH PROFESSOR OF GEOSCIENCES, DEPARTMENT OF GEOSCIENCES, PENNSYLVANIA STATE UNIVERSITY

Dr. ALLEY. Thank you for the honor, Mr. Chairman. Honored Members and guests, I have had the very good fortune to assist the U.S. National Academy of Sciences and the Intergovernmental Panel on Climate Change in their overarching assessments of the issues of climate change. Those assessments have shown us with high scientific confidence that our activities, fossil fuel burning especially, are changing the composition of the atmosphere, that this is changing the climate, that the changes that have happened so far are very small compared to the changes that will occur under business as usual, and that these coming changes will have very large impacts on ecosystems and economies.

This is science. It is not revealed truth. And there are of course uncertainties related to this. Unfortunately, what we find is that around that central estimate, things might be a little bit better, they might be a little bit worse. We have not yet found a lot better, but we have found the possibility of a lot worse. That is especially linked to this issue of abrupt climate changes or thresholds or what are now called tipping points. And in looking at the tipping points, the Arctic is the center of focus. I would like to mention a couple of these; one of them is close to my own research on the Greenland ice sheet. The Greenland ice sheet can exist in part because it is so high left over from the ice age that the top is cold. If you make it too warm so that you lower it enough, a little bit of warming lowers the surface. That makes it warmer yet. A little bit of cooling does not get you back to where you had been, and the ice sheet is no longer survivable.

We know of no way that you can melt a Greenland ice sheet in mere decades. It would be longer than that. But it remains possible that we will reach a temperature over the next decade which will cause melting of the Greenland ice sheet. Greenland is about 23 feet vertically for the world's ocean. It would certainly arrive much more slowly than what we saw in New Orleans, but just as a scaling, the deepest water in New Orleans after the hurricane was 20 feet; and so Greenland would be more water than that for all the coasts of the world if we tip it over.

Another tipping point that comes out of the Arctic is the issue of changes in the North Atlantic circulation. In fact, the IPCC said we have 90 percent confidence that that won't happen, but 90 is not 100. We know in the past that when a lot of fresh water was being put into the North Atlantic, sometimes very large and surprising things happened. One of the outcomes of those large and surprising things was a notable drying in places where now some billions of people rely on rain-fed agriculture. So in the unlikely event that the melt water from Greenland should tip the North Atlantic, there are potentially very large consequences.

The discussion you will hear coming down the line here on sea ice, is that we have seen a reduction in sea ice. We have seen this year a remarkable reduction in sea ice, and it is losing the thick ice that has an easier time surviving for years. And so the possibility exists as you shrink that sea ice loose, the thick ice will soak up more sun because you don't have the reflection; but we tip into a situation in which the summertime sea ice is gone for long periods of time and hard to get back. You will hear some of the impacts. This clearly affects ecosystems; it opens resource exploitation; it opens shipping; it opens coastal villages to waves that had been blocked by the sea ice and quite a number of other changes; and it may propagate into the climate of the lower latitudes with possibly interesting results.

An analogy for predicting this is going to be difficult. You know that if you sit in a canoe and you lean a little bit that the canoe leans a little. If you lean a little more, at some point the canoe flips. Telling exactly where the canoe will flip is very difficult, and we can prove that because people fall in sometimes. They can't predict that. Now, we are changing the atmosphere, but we are changing many other things as well, and nature certainly is out there changing things as well. And so the analogy really should be trying to predict when one might flip a canoe while having a large and rambunctious golden retriever bouncing around in the boat with you. This makes it much more difficult, and there will always be under-certainties in these predictions.

To summarize then, we have high scientific confidence that our fossil fuels and other activities are changing the atmosphere, that this is changing the climate, that the changes we have observed so far are small compared to the changes that will come under business as usual, that this will have large impacts on us and other living things. It will grow to be very costly, and as has been mentioned, there are options for solutions. This is science. It has associated uncertainties. Unfortunately, because of the existence of tipping points and other things, more of the uncertainty is on the bad side and less of the uncertainty is on the good side. Thank you.

[The prepared statement of Dr. Alley follows:]

PREPARED STATEMENT OF RICHARD B. ALLEY[1]

Changes in Arctic Ice With Special Focus on Greenland and Sea Level

Introduction

My name is Richard Alley. I am Evan Pugh Professor of Geosciences and Associate of the Earth and Environmental Systems Institute at the Pennsylvania State University. I have authored over 175 refereed scientific publications in the areas of ice and climate, which are "highly cited" according to a prominent indexing service, and I have given hundreds of presentations concerning my areas of expertise. My research interests focus especially on glaciers and ice sheets, their potential for causing major changes in sea level, the climate records they contain, and their other effects on the environment. I have been a member of many national and international committees, including chairing the National Research Council's Panel on Abrupt Climate Change (report published by the National Academy Press in 2002) and serving on their Polar Research Board. I have contributed to the efforts of the Intergovernmental Panel on Climate Change (IPCC) in various ways, and served as a Lead Author on Chapter 4 (the Cryosphere), and on the Technical Summary and the Summary for Policy-makers of Working Group I of the Fourth Assessment Report, which was released in 2007. I testified to the Committee in February of this year following release of that Summary for Policy-makers; here, I will update some of that testimony and provide special focus on the Arctic.

Ice Changes

Recent authoritative assessments from the National Research Council, the Intergovernmental Panel on Climate Change, and other sources have summarized the strong scientific evidence that human activities are altering the composition of the Earth's atmosphere, causing warming and other changes. There exists increasingly strong evidence for widespread reductions in the Earth's ice, including snow, river and lake ice, sea ice, permafrost and seasonally frozen ground, mountain glaciers, and the great ice sheets of Greenland and Antarctica, as summarized by the IPCC and elsewhere. Strong evidence shows the dominant role of warming, which is primarily being caused by human activities, in this loss of ice.

I will briefly summarize some of these many aspects, especially focusing my attention on the issue of ice-sheet shrinkage and its possible effect on sea-level rise. I will rely on my recent testimony to the Committee, summarizing the recent IPCC report, as well as other and more recent materials as needed.

Snow cover has decreased in most regions, as shown by satellite data tied to limited surface observations. Snow melt is shifting earlier into the spring. Declines in April 1 snowpack have been measured in 75 percent of western North American sites monitored. As summarized in the IPCC Working Group II report, concerns raised by this decline include the dominant role now played by snowpack in supplying summertime water to many regions of the U.S. West. Trends in snow cover cannot be explained solely by changing precipitation (and indeed, in some very cold places snow depth has increased with increasing precipitation), but much of the overall shrinkage of snow cover can be explained by rising temperature.

Freezing of rivers and lakes generally has been occurring later in the fall, with thawing earlier in the spring, giving longer intervals of open water. Coordinated data collection is scarce, however, and the data set not extensive.

Arctic sea ice, formed by freezing of ocean water, has decreased in area and thickness. The change in the summer has been especially large, with ice lost from an

[1] Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author and do not necessarily reflect those of the Pennsylvania State University, the Intergovernmental Panel on Climate Change, the National Research Council, or other organizations. My remarks neither prejudge nor presage the contents of Synthesis and Assessment Product 1.2 of the U.S. Climate Change Science Program, now in preparation and for which I am one of the lead authors.

area twice the size of Texas between 1979 and 2005 (decreasing trend in ice area of seven percent per decade over that interval). Data sets from satellites, tied to observations from ships and submarines, have been critical in documenting these changes. An especially large loss of sea-ice area was observed during summer of 2007, pushing the late-summer minimum sea-ice area approximately 23 percent below the previous (from 2005) record minimum documented by satellite, as reported by the National Snow and Ice Data Center (a research institute at the University of Colorado with funding from NSF, NASA, and NOAA). These very recent results were obtained using well-documented techniques that have been detailed in peer-reviewed publications; thus, while full peer-review and assessment of the latest results are not yet completed, the results are generally considered to be highly reliable. Although shifts in circulation of the ocean and atmosphere may have contributed to the ongoing trend of sea-ice loss, greenhouse gas warming is likely to have been important. (Any Antarctic sea-ice changes fall within natural variability; cooling associated with the ozone hole may be affecting Antarctic climate, a complex subject beyond the scope of these brief remarks.)

Permanently frozen ground (permafrost) and seasonally frozen ground are not readily monitored globally. However, available reports point to overall warming and thawing of this ice in the ground, in response to rising air temperatures and changes in snow cover.

Glaciers and ice caps occur primarily in mountainous areas, and near but distinct from the Greenland and Antarctic ice sheets. On average, the world's glaciers were not changing much around 1960 but have lost mass since, generally with faster mass loss more recently. Glacier melting contributed almost an inch to sea-level rise during 1961–2003 (about 0.50 mm/year, and a faster rate of 0.88 mm/year during 1993–2003). Glaciers experience numerous intriguing ice-flow processes (surges, kinematic waves, tidewater instabilities), allowing a single glacier over a short time to behave in ways that are not controlled by climate. Care is thus required when interpreting the behavior of a particular iconic glacier (and especially the coldest tropical glaciers, which interact with the atmosphere somewhat differently from the great majority of glaciers). But, ice-flow processes and regional effects average out if enough glaciers are studied for a long enough time, allowing glaciers to be quite good indicators of climate change. Furthermore, for a typical mountain glacier, a small warming will increase the mass loss by melting roughly five times more than the increase in precipitation from the ability of the warmer air to hold more moisture. Thus, glaciers respond primarily to temperature changes during the summer melt season. Indeed, the observed shrinkage of glaciers, contributing to sea-level rise, has occurred despite a general increase in wintertime snowfall in many places.

Ice-sheet changes

The large ice sheets of Greenland and Antarctica are of special interest, because they are so big and thus could affect sea level so much. Melting of all of the world's mountain glaciers and small ice caps might raise sea level by about one foot (0.3 m), but melting of the great ice sheets would raise sea level by just over 200 feet (more than 60 m). We do not expect to see melting of most of that ice, but even a relatively small change in the ice sheets could matter to the world's coasts.

A paper published in the journal *Science* earlier this year (Rahmstorf et al., 2007) compared the projections made in the 2001 IPCC Third Assessment Report to changes that have occurred. The carbon dioxide in the atmosphere has followed expectations closely. Temperature has increased just slightly faster than projected, but well within the stated uncertainties. The central estimate of observed sea-level rise is following near the upper edge of the stated uncertainties of the expectations, however, well above the central estimate. Changes in the ice sheets help explain this.

The 2001 IPCC report noted large uncertainties, but presented a central estimate that the combined response of the ice sheets to warming would be slight net growth averaged over the 21st century, slightly reducing the sea-level rise from other sources, with increase in total snowfall on the ice sheets exceeding increase in total melting and with little change in ice flow. Data collected recently show that the ice sheets very likely have been shrinking and contributing to sea level rise over 1993–2003 and with even larger loss by 2005, as noted in the IPCC report and updated elsewhere (e.g., Alley et al., 2007). Thickening in central Greenland from increased snowfall has been more than offset by increased melting in coastal regions. Many of the fast-moving ice streams that drain Greenland (see the Figure, below) and parts of Antarctica have accelerated, transferring mass to the ocean and further contributing to sea-level rise. The total contribution to sea-level rise from the ice sheets remains smaller than the contribution from mountain-glacier melting or from the expansion of ocean water as it warms. However, the existence of the ice-sheet contribution, its important ice-flow source, and the large potential sea-level rise from such mechanisms in the future motivate careful consideration.

Ice-sheet behavior. An ice-sheet is a two-mile-thick, continent-wide pile of snow that has been squeezed to ice. All piles tend to spread under their own weight, restrained by their own strength (which is why spilled coffee spreads on a table top but the stronger table beneath does not spread), by friction beneath (so pancake batter spreads faster on a greased griddle than on a dry waffle iron), or by "buttressing" from the sides (so a spatula will slow the spreading of the pancake batter). Observations at a site in Greenland have shown that meltwater on top of the ice sheet flows through the ice to the bottom and reduces friction there. More melting in the future thus may reduce friction further, speeding the production of icebergs or exposing more ice to melting from warmth at low altitude, and thus speeding the increase in sea level.

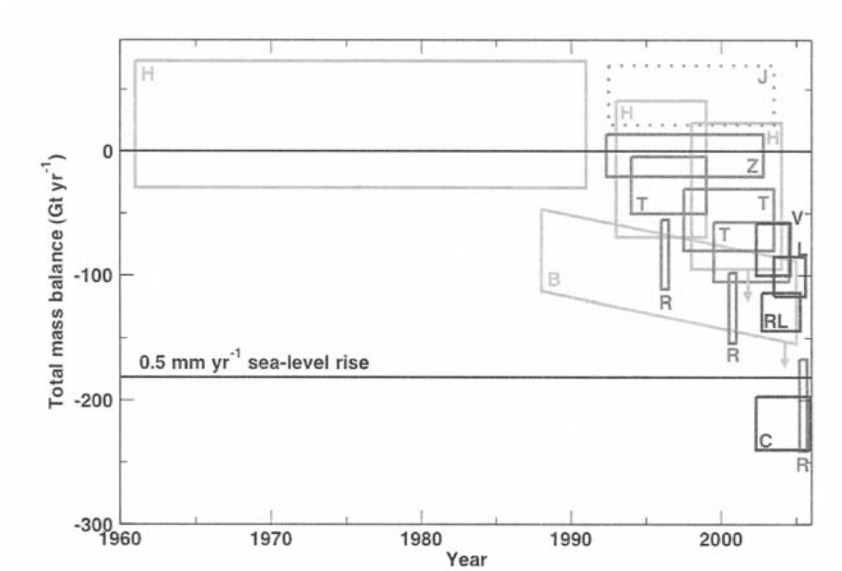
Some early gothic cathedrals suffered from the "spreading-pile" problem, in which the sides tended to bulge out while the roof sagged down, with potentially unpleasant consequences. The beautiful solution was the flying buttress, which transfers some of the spreading tendency to the strong Earth beyond the cathedral. Ice sheets also have flying buttresses, called ice shelves. The ice reaching the ocean usually does not immediately break off to form icebergs, but remains attached to the ice sheet while spreading over the ocean. The friction of these ice shelves with local high spots in the sea floor, or with the sides of embayments, helps restrain the spreading of the ice sheet much as a flying buttress supports a cathedral. The ice shelves are at the melting point where they contact water below, and are relatively low in elevation hence warm above. Ice shelves thus are much more easily affected by climatic warming than are the thick, cold central regions of ice sheets. Rapid melting or collapse of several ice shelves has occurred recently, allowing the "gothic cathedrals" behind to spread faster, contributing to sea-level rise. Many additional ice shelves remain that have not changed notably, and these contribute to buttressing of much more ice than was supported by those ice shelves that experienced the large recent changes, so the potential for similar changes contributing to sea-level rise in the future is large.

Although science has succeeded in generating useful understanding and models of numerous aspects of the climate, similar success is not yet available for ice-sheet projections, for reasons that I would be happy to explore with the committee. We do not expect ice sheets to collapse so rapidly that they could raise sea level by meters over decades; simple arguments point to at least centuries. However, the IPCC report is quite clear on the lack of scientific knowledge to make confident projections. Naïve comparison of tabulated projections of sea-level rise in the Third and Fourth Assessment Reports of the IPCC might lead a reader to the mistaken conclusion that the more-recent assessment has reduced uncertainties and concerns about sea-level rise. However, the newer report specifically notes that projections exclude contributions to sea-level change from "future rapid dynamical changes in ice flow" (Table SPM–3) "because a basis in published literature is lacking" (page SPM14), so that it is not possible to "provide a best estimate or an upper bound for sea level rise" (page SPM15). (The new report also notes a similar difficulty arising from lack of knowledge of feedbacks in the carbon cycle, and referring to the possibility that warming will cause much release of methane and carbon dioxide from soils in the Arctic, sediments under the sea, or elsewhere, contributing to more warming.)

Much discussion has focused on the question of "tipping points" or thresholds for abrupt change. Clearly, at sufficiently warm temperatures, ice will melt. As discussed in the IPCC report, sufficiently warm temperature, sustained for a sufficiently long time, will melt the Greenland ice sheet, with more than a few degrees of warming sustained over a few centuries to millennia being a reasonable approximation but with no agreement on exact values. This is often considered to represent a tipping point because a small cooling then would not restore the ice sheet even if sustained for a long time; the warming associated with the loss of the high-elevation and reflective, hence cold, ice surface would overcome any small subsequent cooling. Recent simple modeling (e.g., Schoof, 2007; also see Dupont and Alley, 2005) supports earlier work that "tipping point" behavior might be observed in Antarctica as well, with warming sufficient to weaken or remove certain ice shelves triggering ice-sheet changes to a new state. These processes remain very poorly understood, and confident assessment of their likelihood or rate is not now possible.

Synopsis

In summary, with high scientific confidence, changes are occurring in much of the world's ice. These are being caused primarily by warming. Globally, the warming is largely being caused by greenhouse gases being released to the atmosphere by human activities. Shrinkage of the large ice sheets was unexpected to many observers but appears to be occurring, and the poor understanding of these changes prevents reliable projections of future sea-level rise over long times.



Recently published estimates of the mass balance of the Greenland ice sheet through time (modified from Alley et al., 2007). A Total Mass Balance of 0 indicates neither growth nor shrinkage, and -180 Gt yr^{-1} indicates ice-sheet shrinkage contributing to sea-level rise of 0.5 mm/year (one inch in about 50 years), as indicated. Each box extends from the beginning to the end of the time interval covered by the estimate, with the upper and lower lines indicating the uncertainties in the estimates. A given color is associated with a particular technique, and the different letters identify different studies. Two estimates have arrows attached, because those authors indicated that the change is probably larger than shown. The dotted box in the upper right is a frequently cited study (Johannessen et al., 2005) that applies only to the central part of the ice sheet, which is thickening, and misses the faster thinning in the margins.

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BIOGRAPHY FOR RICHARD B. ALLEY

Dr. Richard Alley is Evan Pugh Professor of Geosciences and Associate of the Earth and Environmental Systems Institute at The Pennsylvania State University, University Park, where he has worked since 1988. He was graduated with the Ph.D. in 1987 from the University of Wisconsin–Madison and with M.Sc. (1983) and B.Sc. (1980) degrees from The Ohio State University–Columbus, all in Geology. Dr. Alley teaches, and conducts research on the climatic records, flow behavior, and sedimentary deposits of large ice sheets, to aid in prediction of future changes in climate and sea level. His experience includes three field seasons in Antarctica, eight in Greenland, and three in Alaska. His awards include the Seligman Crystal of the International Glaciological Society, the first Agassiz Medal of the European Geosciences Union Cryospheric Section, a Presidential Young Investigator Award, the Horton Award of the American Geophysical Union Hydrology Section and Fellowship in the Union, the Wilson Teaching Award and the Mitchell Innovative Teaching Award of the College of Earth and Mineral Sciences and the Faculty Scholar Medal in Science at Penn State. Dr. Alley has served on a variety of advisory panels and steering committees, including chairing the National Research Council1s Panel on Abrupt Climate Change, and has provided requested advice to numerous government officials in multiple administrations including a U.S. Vice President, the President's Science Advisor, and a Senate Committee. He has published over 170 refereed papers, and is a "highly cited" scientist as indexed by ISI. His popular account of climate change and ice cores, The Two-Mile Time Machine, was chosen science book of the year by Phi Beta Kappa in 2001. Dr. Alley is happily married with two children, two cats, and two bicycles, and resides in State College, PA, where he coaches recreational soccer and occasionally plays some.

Chairman MILLER. Thank you, Dr. Alley. A better analogy might have been a Labrador retriever.

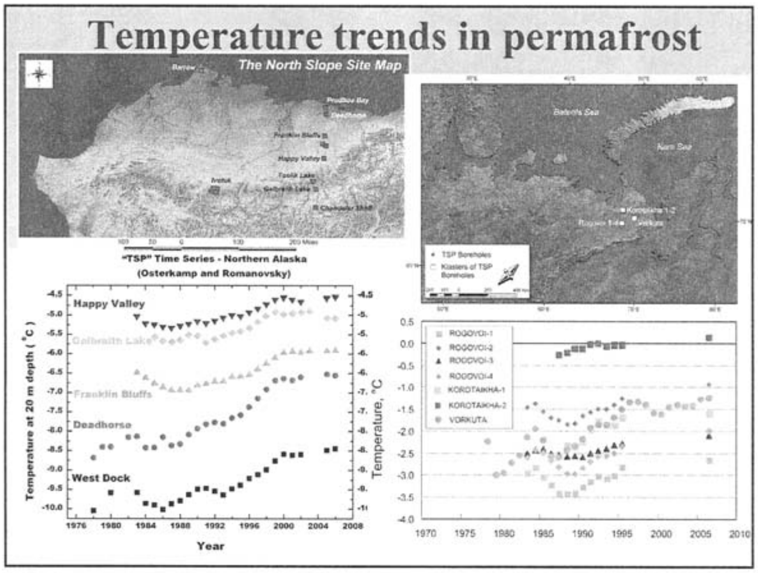
Dr. Juday.

STATEMENT OF DR. GLENN PATRICK JUDAY, PROFESSOR OF FOREST ECOLOGY, SCHOOL OF NATURAL RESOURCES AND AGRICULTURAL SCIENCES, UNIVERSITY OF ALASKA AT FAIRBANKS

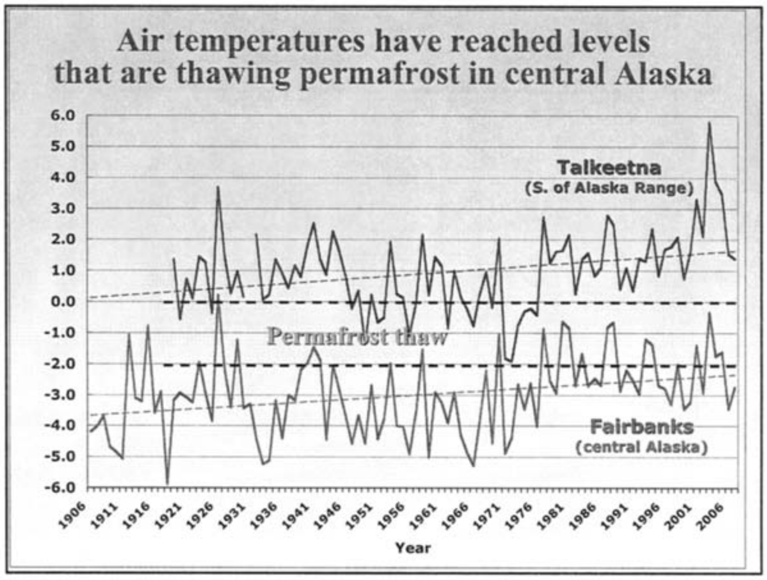
Dr. JUDAY. Thank you. I just want to point out at the beginning that I am bringing information that was requested from Vladimir Romanovsky and John Walsh as well who are specialists respectively in permafrost and sea ice, and I will try not to misconstrue the information that comes from publications that I have cited in the presentation; and if there are more detailed questions, I can certainly have them respond if it goes beyond my expertise. I am the frost guy.

First, on permafrost, permanently frozen ground or at least ground that has remained in a frozen state for two years underlies a significant part in the northern portion of the planet and in certain places can contain large lenses of pure water ice but a lot of frozen organic material. We have recognized three kinds of permafrost, the continuous permafrost in the coldest portion; the discontinuous permafrost where the temperatures are marginal, and local, side factors take over the determination of whether you are going to stay in the frozen condition or not; and then in the southernmost extent, only the very coldest spot localities in the landscape have permafrost.

Permafrost temperature measurement has not been a big field in science, and very few people have done that work. Dr. Romanovsky is one of them and taking over some early work done by Dr. Tom Ostercamp.



Here you see a plot of the actual frozen ground temperature trends since the late 1970s, so we have about a 30-year perspective. The trend is up. Equations that predict the temperature of permafrost work exceptionally well with just a few input factors, air temperature obviously is one of them, but snow cover is an extremely important one. And we have seen a very strong rise and then a kind of leveling or even a backing off a little bit because of a trend toward decreasing snow cover. All the models say more snow cover under the warming Earth, and all the data say—not quite all the data but a significant number of stations, they have had less.

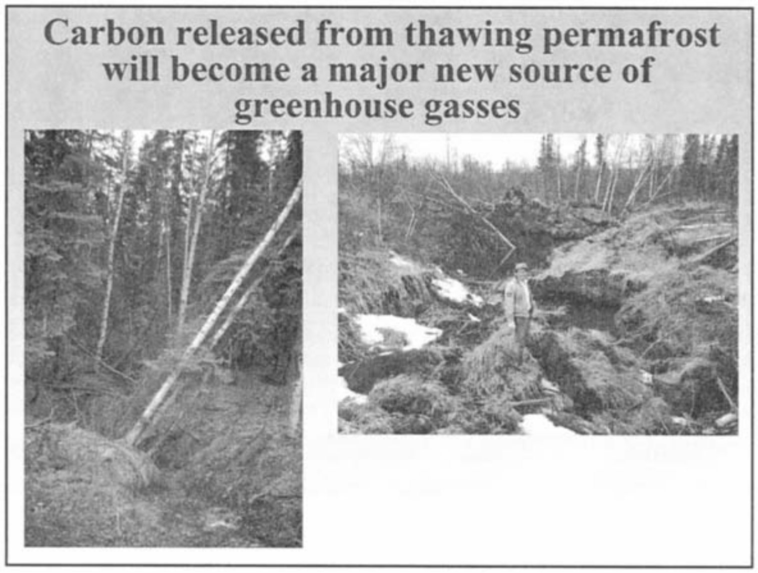


Here is a depiction of nearly a century worth of air temperature data from Central and Southcentral Alaska. You see that permafrost forms in the region when the mean annual temperature is between 0°C/32°F and -2, and you see that in the Talkeetna area in Southcentral Alaska with the decisive move of temperatures about 30 years ago in the regime shift, we are completely out of that zone. And in Central Alaska, in Fairbanks, about half of all years are spent in the zone where at least some thawing will begin.

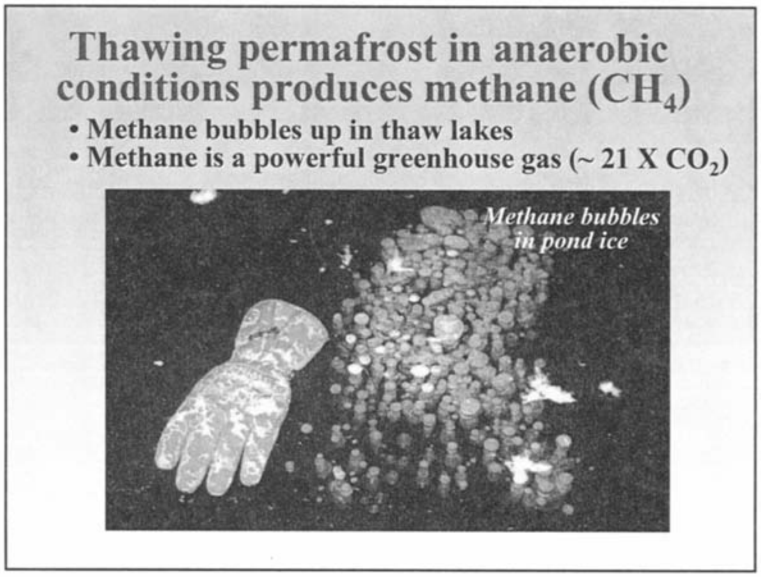
So what does this mean? Just allowing for not an acceleration but a continuation of recent trends in temperatures, the red areas depicted here would be those that would thaw ultimately. Again, there is a long lag effect because there is a lot of insulation power in that material that is on the ground, and it goes some depth into the ground; but the initiation of thawing would begin in the areas depicted there.

Now, so what? Big deal. Who cares? Well, it is a big deal for a couple of things. Linear infrastructure is the thing most at risk, railroads, roads, pipelines, because you have to get from point A to point B, and avoidance is not an option. So that means you got to deal with it. It can be engineered, but it is going to cost. Some structures, such as the pipeline, advance the technology of dealing with permafrost with natural convected cooling fans and things, but those were designed for again, mean annual temperature. They are engineered for it and achieving a certain amount of cooling and a careful look may need to be paid at the design capacity of those systems.

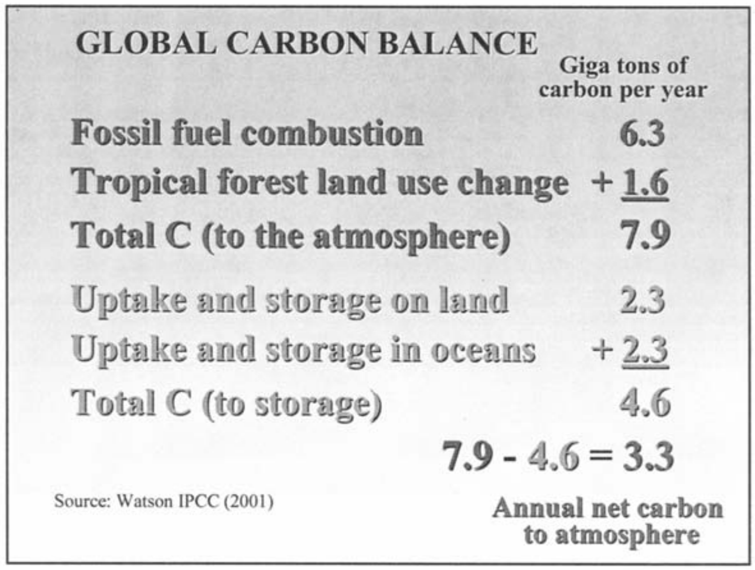
Now buildings and building footprints on permafrost can be a significant problem. If the building is small and low value enough, maybe a low-cost solution like just adjustable foundations can work. In other cases, if you are going to put a major investment in the ground, you are dealing with probably something else entirely.



Now, perhaps of more global significance is the role that thawing the permafrost is going to have in releasing as you pointed out, Mr. Chairman, the greenhouse gases into the atmosphere. Spontaneous thaw of permafrost is observable on the landscape today as you can see. It can come out in two different forms, one, CO_2 when the decomposition is aerobic, but it can also come out as methane when the conditions are anaerobic. And as lenses of ice thaw and then melt, the ground subsides, fills with water, creates anaerobic conditions, lack of oxygen, what comes out is methane. It generally has been vastly underestimated in the past, and the reason is it comes out in a way that is hard to measure, and that is these bubbles.



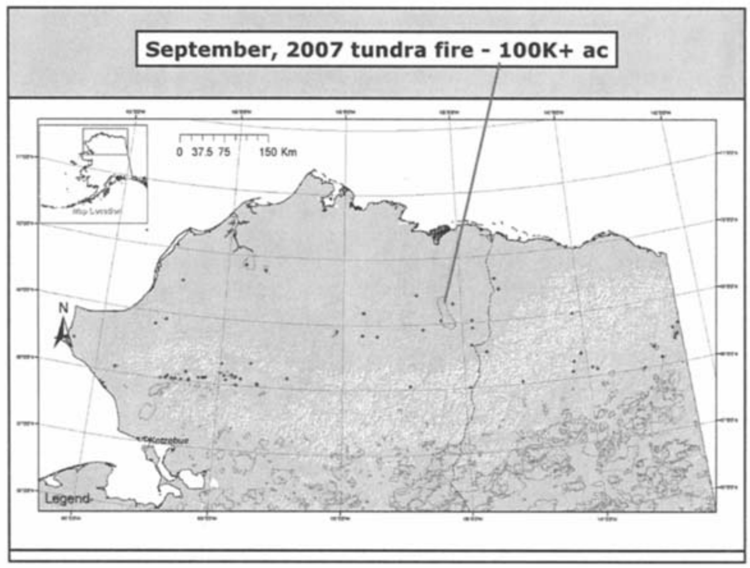
Here you see the bubbles trapped in clear water ice. That methane of course is an extremely powerful greenhouse gas, and per unit volume is 21 times more powerful in producing a greenhouse effect.



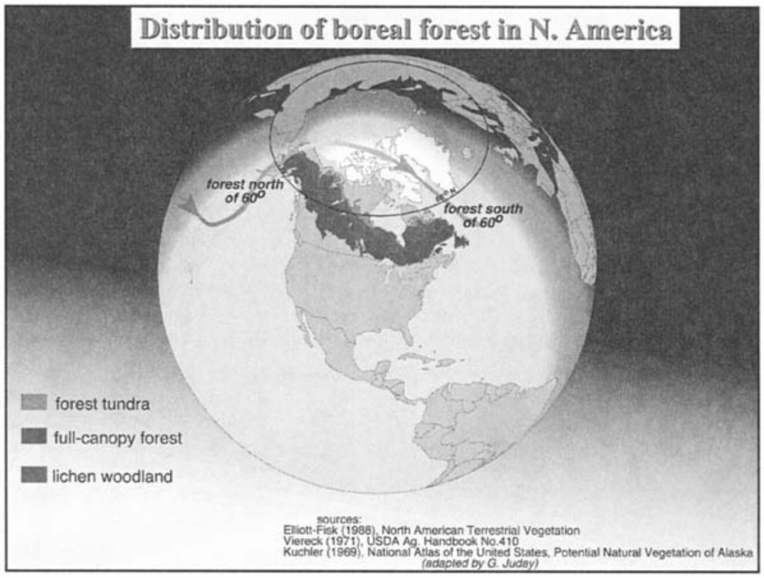
This, now, collapsed ponds and efoliation or bubbling up of methane is a widespread phenomenon observable in parts of Alaska and in Siberia.

So what does this all mean? Let us get some numbers on the table here. As you pointed out, gigatons of carbon per year. Recent years we have been combusting about 6.3. Essentially permanent land use change in the tropical forest regions has been usurping the uptake so that we get 7.9. However, fortunately for us, uptake in storage on land has been about 2.3 and similar amount in the world ocean, so that the net problem that we experience is an uptake of 3.3, which is considerably less than the 7.9. I am afraid I have to tell you that there is every indication that the ability of land ecosystems to store carbon is going down and probably down very significantly, and they may very soon be net neutral.

Now, in terms of storage, it is just a slightly different story. The tundra and the boreal systems are pretty good at growing plant material but really not so good at decomposing it because of the cold soils. The tropical forests are some of our most productive systems on the Earth, that is uptake of carbon, but they decompose just about the same amount, very low storage. So in that storehouse, that locker of carbon that makes up the ground layer in the cold regions, we are seeing some very momentous developments. For example, we had a September tundra fire, extremely rare event; and it was not a small one, it was a very, very large one. It was over 175,000 acres.

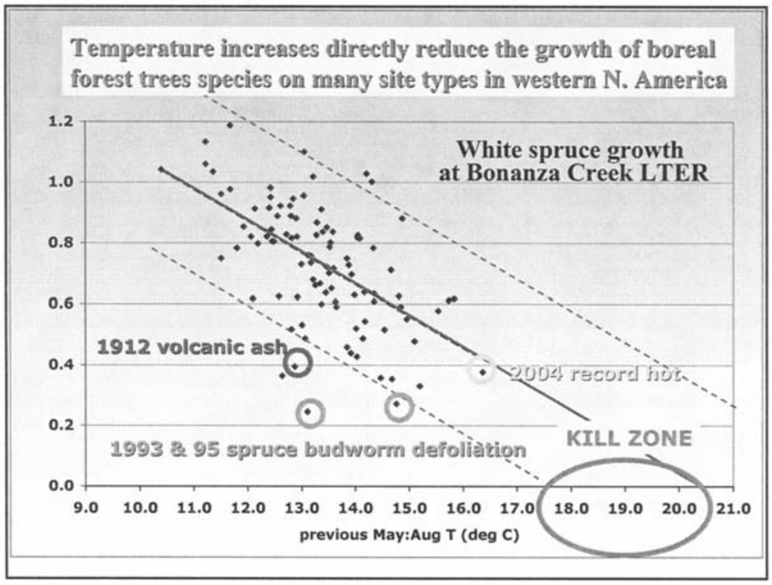


You can see the footprint of the fire on the north slope of Alaska here. We have a reasonable record of wild land fire in Alaska for 57 years, and the record is not being kept according to the fuel type that burned, whether it was tundra or whether it was forest; but I asked the Alaska Fire Service, and they produced this statistic. If you draw a line at 68 North, north of that there just generally aren't forests. So let us focus on that, and we will be sure that we are getting a tundra single.



This is as clear as the evidence gets. There were no tundra fires. Then came a period when at peak warmth we had one, two, and now a very substantial increase in tundra fire.

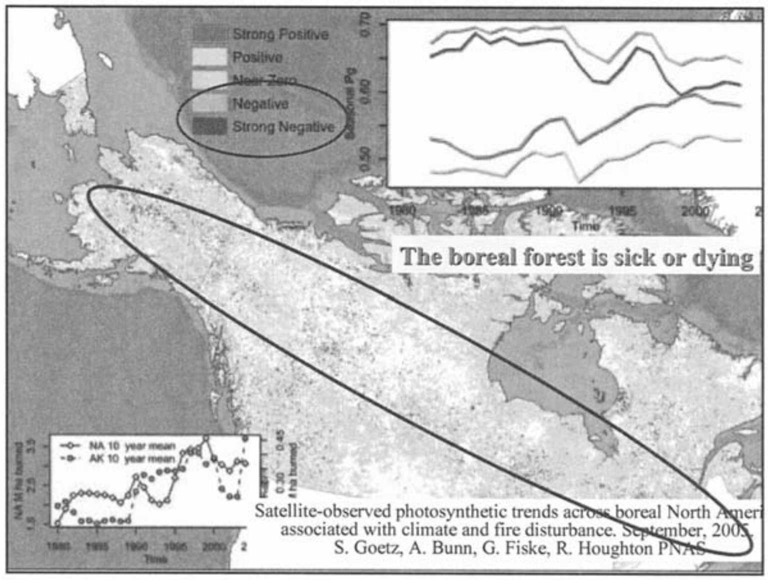
Now, let us transition a little further south of the boreal forest, that is that belt of conifer-dominated forest land south of the tundra. It has this tilt to it, so that in the western North American boreal is further north and more productive in equivalent latitude than in eastern North America, and that is because of the introduction of warm air from the south by the storm systems and its export with a little boost from the cold ice regions of eastern North American Arctic.



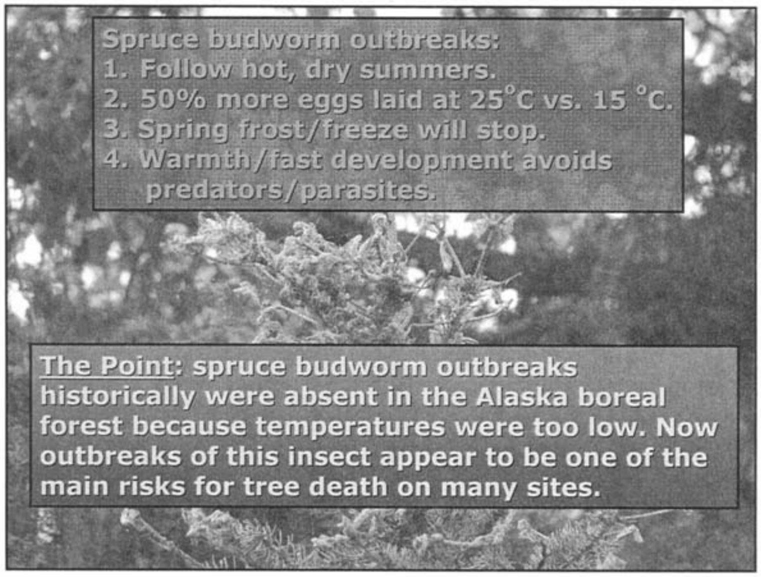
This is a graphic I actually produced for the Select Committee that I testified to two weeks ago. We were going to this stand when we had to cancel the trip this summer but did have the hearing, and in that stand that I have been monitoring for 20-some years, I just plotted the predictive index of temperature that tells us how much the forest should grow versus the ring width, which is the vertical axis there of this sample. And you can see that warmer, the less it grows. The interesting thing is where the index doesn't work for example, the forest grew less than the prediction. There is a good reason for that, for example, spruce bud worm outbreaks, the trees covered with volcanic ash.

Here is our record-warm summer, 2004, which predicted the growth in 2005; and you see there is a zone of uncertainty around the trend line which means that we are extremely close to what you could call the kill zone, lethal temperatures, where the trees would spontaneously die in the forest because it is just too warm for their adaptive capabilities. You can see that is about one degree C.

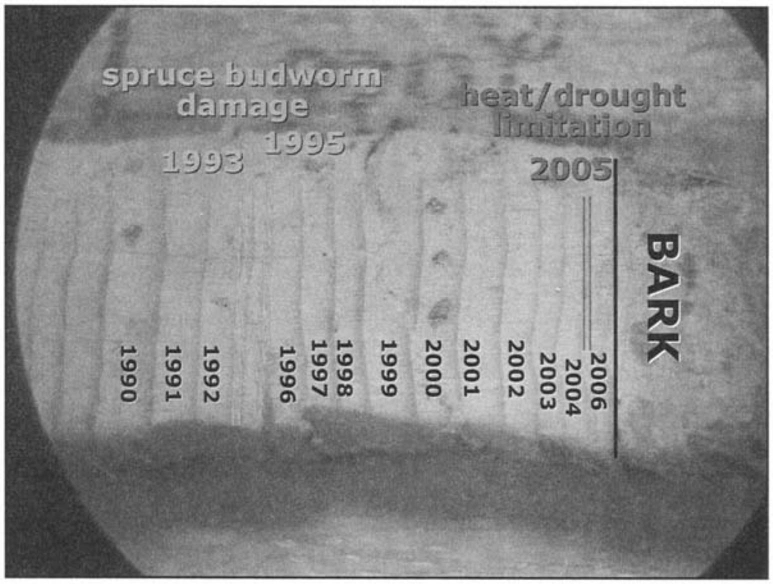
Now, is that a local phenomenon? Is that just something I found in my plot in my course?



This is a satellite observed, photosynthetic trends measured from 1980 through 2003 by Scott Goetz, and these are pixels depicted here, 10-by-10 kilometer chunks of the Earth; and if during that period of time the photosynthetic trend was down or strongly down, it is colored blue, and as you can see, the entire boreal forest of North America shows considerable amount of blue or neutral—no large increases.



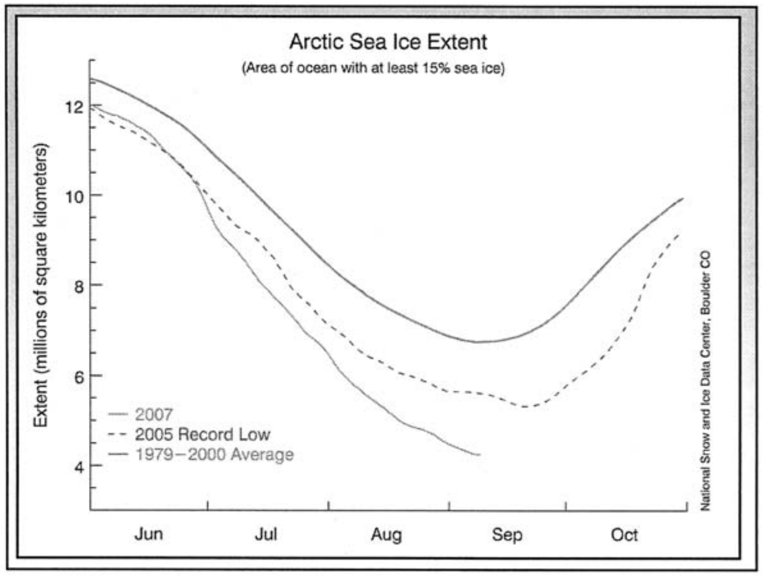
We are seeing things for example the spruce bud worm now exhibiting outbreak behavior. It is an insect that hatches, feeds on the foliage like this, and leaves the tree in this condition after it is done feeding, and there is a direct temperature control. It is a major insect species in the Canadian boreal forest. We have never seen it in outbreak mode in the northernmost boreal forest. Now it is. Temperatures were too low, now they are warm enough, now it is killing the trees.



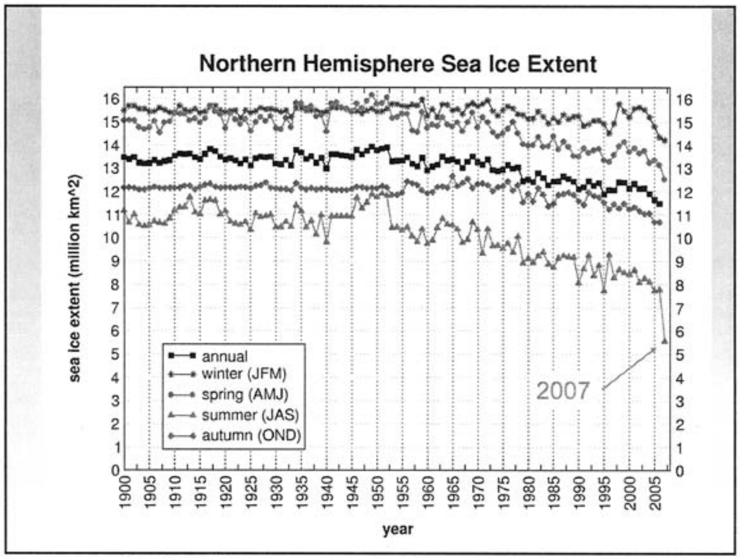
You can see clearly a record in tree growth. There is the 2005 hot, dry year. There is the spruce bud worm outbreak. This is killing the growth of the forest. But that is not all. There is leaf scorch on birch trees. It is the last symptom to appear before the tree dies and when it is running out of water. A three-tone color in which there is death or necrosis of tissue around the margin and the breakdown of chlorophyll so that you have the yellow zone, and finally, the green is retained only around the veins where the water can be first introduced into the leaf. Similar kill zone is apparent in our most sensitive sites that grow birch, and in fact, of the 2004 temperature indicating, well, we entered the kill zone. So do we have dead trees? Yes. Head of the Forest Health Survey took my research seriously, and so he went out and he looked and he found dead trees that were not killed by insects that apparently were the result of this phenomenon.

Fires, we had the record fire year in the season 2004. If you take the northeast quadrant of Alaska, 15 to 20 percent of all forest land burned in one year. Then something very close to that happened the next year, another seven to 10 percent. So in a two-year period, we had one-fourth to one-third of all forest land in the northeast quadrant of Alaska burned.

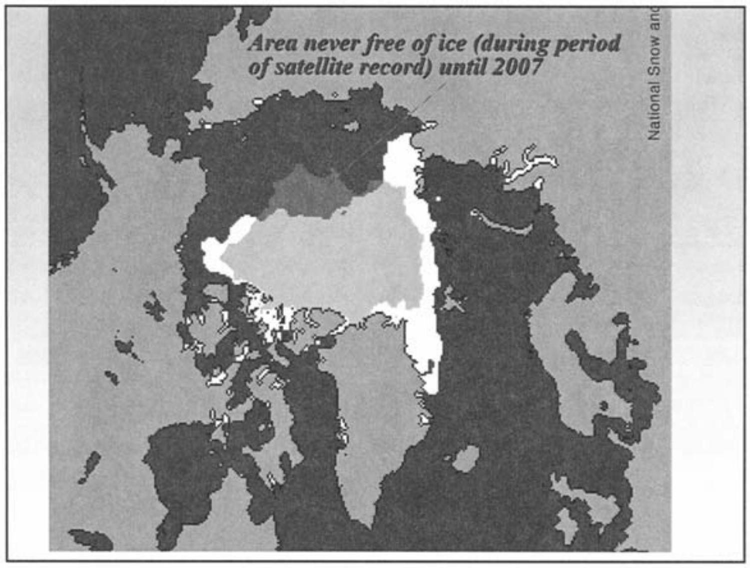
Finally, I will just do a couple of comments about sea ice that is going to be the subject of a lot of discussion from a couple perspectives here.



This is the depiction of the sea ice cover as of I think it is a week-and-a-half ago. You see the long-term mean in the upper black line. The dashed line was the previous record low, the 2005 record, and you see 2007, 25 percent below the previous low record which was set only two years ago.

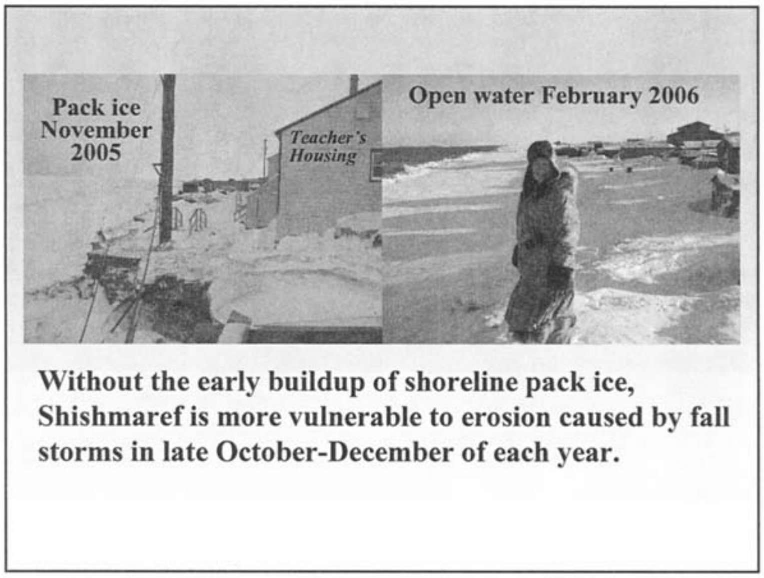


Here is a depiction of the seasonal and annual sea ice extent. There are two different standards for measuring this. In case there is some confusion in some of the numbers thrown around, just be aware of that. There is this sea ice edge, and there is also total sea ice cover, which accounts for leads and openings further north but as you can see, a radical reduction in a one-year period in the sea ice cover at the end of the summer.



And perhaps as significant, there are these zones of retreat that rotate around along with the movement of the ice in the polar gyre that have brought open water conditions very far north in the past but usually in a lobe or a finger in one particular sector of the arctic. But during the period of the satellite record, no open water has ever been seen in the area depicted here, and that was entirely free of ice and contiguous with other open water all the way to the south.

The last point I will make is a little community of Shishmaref, you may have heard of it, had the opportunity, in the hearing two weeks ago, to be accompanied by Mayor Stanley Tocktoo who is mayor of this community, and just to give you a picture of what they are dealing with, these are self-reliant people who work hard. They engage in hard, physical labor, not for cash but for a considerable period of the year to get the food they need. They go out on the ice to hunt. They gather, they fish, they engage in these activities; and they can tell you, their environment is changing. Pack ice should be presenting and forming right about now; it traditionally has been, giving them access to the seals they hunt and a very important part of their annual diet; and they are not able to be safely on the ice at this time.



For example as you see here in February and the erosion that is now possible from the storm and the fetch that the wind has access to churn and push this water because of the disappearance of the sea ice is causing enormously accelerated erosion, and the community is literally being destroyed.

So in summary, the permafrost definitely is warming. The first stages of thawing are obvious. The boreal forest has burned, is sick, or is dying on a very extensive scale. Its ability to store carbon is being severely compromised, and immobilization of carbon that has previously been stored is well under way. Sea ice is treating and also thinning. I have touched on other things such as glacier melting, sea level rise, lakes drying, species movements, etc., but if you have questions on those areas, I will attempt to answer them. Thank you.

[The prepared statement of Dr. Juday follows:]

PREPARED STATEMENT OF GLENN PATRICK JUDAY
WITH ASSISTANCE BY
VLADIMIR ROMANOVSKY, PROFESSOR OF GEOPHYSICS, UAF
JOHN WALSH, PRESIDENT'S PROFESSOR OF CLIMATE CHANGE, UAF
F. STUART CHAPIN III, PROFESSOR OF ECOLOGY, UAF
STANLEY TOCKTOO, MAYOR OF SHISHMAREF

Climate Change in the Alaskan Arctic and Subarctic: A Vast Panorama of Comprehensive Environmental Change

Mr. Chairman and Members of the Committee, I would like to thank you for the invitation to present some information to the Committee concerning recent climatic changes, their current effects, and the likely future situation in the Arctic and Subarctic. I have been assisted in preparing my presentation by senior colleagues at the University of Alaska in subjects related to climate change of interest to the Committee.

I have had the opportunity to work with these colleagues in teams involved in integrated climate change assessment, and they have provided publications and data for this presentation. I have attempted to restrict my characterization of their findings to these sources, but if further clarification is required I will convey the issues back to them for a definitive response.

I also recently had the opportunity to accompany Mayor Stanley Tocktoo in recent meetings and testimony before Congress, and he generously shared information from the presentation he used which was assembled by the community of Shishmaref, Alaska.

The focus of my presentation is the American portion of the Arctic—in Alaska. For a comprehensive review of the whole region, especially the background setting and processes of this unique part of the world, I refer the Committee to the Arctic Climate Impact Assessment:

www.acia.uaf.edu

This written statement is meant to accompany the PowerPoint presentation I have provided the Committee, which has maps, graphics, citations, and other specific details.

1. Permafrost.

One of the unique features of the Arctic and Subarctic regions is the extensive presence of cold soils and permafrost. Permafrost is soil and ground material that remains frozen for more than two years. Permafrost forms when mean annual temperatures are below freezing, generally in the range of 0 to -2 degrees C. Differences in soil texture, water content, and site characteristics can allow permafrost to form at annual temperatures equal to freezing, or require annual temperatures well below freezing. Permafrost everywhere disappears at a great enough depth where heat from the geothermal gradient overcomes cold surface temperatures. Permafrost (the frozen material itself) occurs at a range of temperatures from near 0 degrees C to ten or more degrees below. As a result, the coldest regions make up a continuous permafrost zone across the landscape. Slightly warmer cold regions are within the discontinuous permafrost zone, where occurrence of the frozen state is influenced by local factors. Areas with only isolated or sporadic masses of permafrost make up a third zone.

Permafrost can be ice-rich, in which case thawing melts the frozen water content and causes ground subsidence, or it can be dry, leading to little potential for surface change between the frozen or thawed condition. Temperature trends in permafrost are increasing clearly, and across nearly all the Arctic and Subarctic. Permafrost temperatures are in exceptionally close agreement with predictive models of mean annual air temperature, snow depth and duration, and soil composition. Reliable permafrost temperature measurements generally date back only to about 1970, although the predictive models can be run backward in time with good confidence. Observations of permafrost thawing at its southernmost limits in the U.S., Canada, and central Asia are widespread.

Surface-disturbing activities, such as road and building construction, and natural events such as wildfire, can tip the thermal equilibrium toward thawing in warmer permafrost regions, and have for some time. But these processes are producing more widespread effects in recent warmer conditions. All the permafrost in central Alaska has been trending upward in temperature, and now nearly all of it is only -0.5 to -2.0 degrees C. Annual air temperatures above freezing are now occurring across large portions of the permafrost regions, and are certain to thaw the permafrost if sustained. The only questions are exactly where (the sequence of microsites) and how fast. Calculations indicate that a substantial fraction of existing permafrost has started or will start the thaw process (which may take decades or centuries to complete to the greatest depths) in the next several decades.

Linear infrastructure (roads, pipelines, railroads, etc.) are at most risk from thawing permafrost, because such developments must proceed from point A to point B at some location, making avoidance of permafrost unworkable. Developments and structures can be engineered to minimize thaw or even keep ground material frozen. But such engineering features are substantial costs and are not easily retrofitted.

Permafrost and other cold soils hold an amount of carbon that, if it were entirely combusted, would double atmospheric CO_2 content. Warming and/or thawing of the cold or permafrost soils is beginning to move this carbon into the atmosphere in a variety of ways.

Some of the largest wildland fires or burning seasons on record have occurred in the Arctic and Subarctic in direct response to increasing temperatures and drying.

2. Boreal Forest.

About half of the world forest area has been converted to other land uses on a long-term or essentially permanent basis. The boreal forest is the most stable by far of all the world's forest regions in terms of forest conversion or destruction. Until recently the boreal forest has also been the most ecologically intact of the world's forest regions. These characteristics and the substantial annual surplus of growth (which removes carbon from the atmosphere) compared to decomposition (which releases carbon to the atmosphere) made the boreal forest one of the key land areas of the world in naturally reducing the buildup of greenhouse gasses.

Now, a variety of high temperature-related stresses have become pervasive in much of the boreal forest, especially in Alaska, seriously affecting its ability to continue to store carbon at the same levels as the past.

Measurement of tree-ring growth versus temperatures over the last century or so have shown that many trees on many site types consistently grow less in the warmer years and grow more in the cooler years. This negative response to warming has only been appreciated for the last decade or so, and it has been shown to be a consequence of high temperatelure-caused lack of water that induces plant shut-down.

Because the temperature increases during the last few decades in central Alaska have been among the greatest on the planet, the tree growth reduction effect has been considerable. Temperatures that consistently predict the growth of trees in boreal Alaska are approaching lethal limits. During the record warm summer of 2004 and 2005, some tree death from drought appears to have occurred in populations of Alaska birch.

High temperatures also trigger outbreaks of forest-damaging or forest-killing insects. Outbreaks of known or suspected high temperature-related insects have occurred simultaneously across boreal Alaska and now much of western Canada.

Finally, wildland fires have increased to record levels and burned one-fourth to one-third of all forest land in the northeast (hottest and driest summers) quarter of Alaska.

3. Arctic Sea Ice.

Arctic Ocean sea ice is a complex and dynamic phenomenon. A variety of physical processes occur as sea water nears freezing temperatures, changes from the liquid to the solid state, and coalesces into larger scale structures.

Of key biological importance is the expansion of water to maximum density at four degrees C, which then causes sinking in the water column to the bottomwater at that temperature. The sinking action forces or displaces older, nutrient-rich bottomwater upward, allowing a bloom of marine productivity during the time of year that sunlight is available. Ice crystal and structures themselves serve as secure attachment point for specially adapted algae, with is another unique source of marine production in these cold waters compared to the rest of the world ocean.

The Arctic is the world's most land-dominated ocean. Several northward-flowing rivers transfer relatively large amounts of heat, freshwater, and nutrients into the ocean. The result of all the processes promoting productivity is a highly productive marine ecosystem in the northern, ice-edged seas, in distinct contrast to the level of annual production in nearby land ecosystems. It is no co-incidence at all that the cultures and current activities of the native people of the Arctic are highly oriented to hunting the abundant marine mammals, birds, fish, and other resources of the productive continental shelves and shores of their homeland.

During the strong global warming (probably due to orbital influences on the amount of solar energy reaching the far north) that decisively ended the last ice age starting about 12,000 years ago, a period of seasonally ice-free Arctic Ocean occurred probably about 8,000 years ago. A gradual cooling began between 6,000 years ago, and continued with irregular warm periods, until the last century.

Comprehensive satellite-based records of the mount of sea ice start in the late 1970s. But the orientation of the Arctic residents and harvested resources toward the sea, visiting fleets, and records from explorers and the early scientific era give a good picture of the extent and location of sea ice for the last century and a half, with trends and low precision before, and very high precision for the most recent 30 years.

Changes in sea ice that are unique in the last several centuries have appeared suddenly and extremely strongly in the last five years, culminating in an extreme record of ice disappearance in September 2007. Influx of warmer Atlantic and Pacific Ocean bottom water, expulsion of multi-year ice, ice thinning, coating of the ice with small, dark soot particles, and cycles of atmospheric currents all played a role in the recent disappearance of Arctic sea ice. But the feedback influence of converting sunlight-reflective ice with sunlight absorbing open water on over huge areas of the Arctic Basin, represent one of the strongest feedbacks to global temperature increases in recent times of the planet. This change is not likely to be reversed soon.

As I am sure the Committee is aware, a whole new set of strategic international relations has appeared as a result of the Arctic Ocean now becoming navigable to ordinary marine vessels. The residents of the Arctic now have a more difficult time gaining access to harvestable food resources on stable or predictable ice platforms. The lack of near-shore ice may be reducing local marine productivity by putting the ice edge over deep water. Finally, the existence of large areas of open water allows more frequent and stronger storms to batter the shore which is devoid of ice protection. The resulting extreme acceleration of shoreline erosion is displacing people of the region.

I thank the Committee for focusing on these historic, rapidly unfolding, and powerful events, and I offer to assist Members in obtaining additional information.

BIOGRAPHY FOR GLENN PATRICK JUDAY

Glenn Patrick Juday, is Professor of Forest Ecology and Director of the Tree-Ring Laboratory in the School of Natural Resources and Agricultural Sciences at the University of Alaska Fairbanks, where he has worked since 1981. Dr. Juday is currently a Senior Investigator in the NSF-supported Bonanza Creek Long-Term Ecological Research site in central Alaska. His research specialties include climate change, tree-ring studies, biodiversity and forest management, and forest development following fire. He is the Lead author of the chapter on Forests and Agriculture of the Arctic Climate Impact Assessment, and a contributing author to the chapter on Biodiversity Conservation. Dr. Juday has served as science advisor for several U.S., Asian, and European television programs on climate warming, including the PBS series Scientific American Frontiers His research results were discussed in two issues of *National Geographic* magazine in 2004. He has briefed and led trips for several Members of Congress. Dr. Juday was recognized for outstanding accomplishments as Chairman of Forest Ecology Working Group of the Society of American Foresters in 2000. He is the author of over 30 scientific peer-reviewed journal articles and book chapters including *Nature, Climatic Change, Global Change Biology, Forest Ecology and Management,* and *Canadian Journal of Forest Research.* He has book chapters published by Oxford University Press, Cambridge University Press, and *Annual Review of Ecology and Systematics.*

Dr. Juday received his B.S. *summa cum laude,* in 1972 in Forest Management from Purdue University, and his Ph.D. in 1976, in Plant Ecology from Oregon State University. He completed a Rockefeller Foundation Post-Doctoral Fellowship in Environmental Affairs, 1976–1977 serving as Executive Chair of the Oregon Natural Area Preserves Advisory Commission. He spent a sabbatical in the headquarters of The Nature Conservancy in Arlington Virginia in 1988.

Chairman MILLER. Thank you, Dr. Juday. I did not want to interrupt that because it is obviously important, but if you would try to summarize some of your testimony, it would be helpful to the Committee.

Dr. Haseltine.

STATEMENT OF DR. SUSAN D. HASELTINE, ASSOCIATE DIRECTOR FOR BIOLOGY, U.S. GEOLOGICAL SURVEY, U.S. DEPARTMENT OF INTERIOR

Dr. HASELTINE. Thank you, Mr. Chairman, and Members of the Subcommittee for the opportunity to participate in today's hearing. I would also like to introduce one of our sea ice researchers from Alaska, Dave Douglass, sitting behind me. Dave was a member of the team that produced the reports that I am going to talk about today.

Global climate change is one of the most complex environmental challenges obviously facing society today. And while climate change is a natural, continuous Earth process, changes to the Earth's climate are also related to human activities; and whether the causes are natural or from human influence, the USGS scientists focus on understanding the impacts of climate change and potential adaptive strategies for managing natural resources and ecosystems in the face of these changes on the landscape.

The USGS conducts scientific research to understand the likely consequences of climate change using three primary strategies, first by studying how climate has changed in the past and using the past to forecast responses into the future, second by distinguishing natural and human-induced changes where possible, and third by quantifying both biological and physical responses to climate change.

Today I want to discuss the changes that have been observed and modeled in Arctic sea ice and their impacts on the top predator in that environment, the polar bear. Data from the satellite record for the past three decades shows a decline of about 10 percent per decade in the minimum annual sea arctic sea ice extent at the end of the summer melt season; and in this year's melt season, as has been noted, the minimum ice coverage in the Arctic was measured at about four million square kilometers, and that represents about 40 percent less ice than was observed in 1979 when we had the first satellite records.

While rising Arctic air temperatures have certainly contributed to this loss of sea ice, there are several other factors that have interacted to accelerate the loss, and there is a growing scientific concern that the synergism of recent events in the Arctic, regardless of their origin, may have already pushed the Arctic past a threshold of cascading change.

The USGS and our partners around the Arctic have a robust baseline of data for assessing polar bear populations, for defining essential polar bear habitat in the sea ice, and for making projections of future population status. The nine recently released USGS reports build on this history of research and collaboration and culminate in a new range wide forecast of polar bear status under various projections of future climate change. To forecast the status of polar bear population worldwide during the 21st century requires modeling information on the future habitat conditions for polar bears and also on their projected population status. We used ten of the general circulation models that were used in the IPCC Fourth Assessment Report in projecting this change, and those ten were the ones that most closely mirrored the sea ice change that we have observed over the last few decades.

We used middle-of-the-road carbon loading scenarios in making our projections, and we developed a future model then that combined information about annual and seasonal sea ice change, habitat preferences for polar bears, and population demographics to predict likely polar bear numbers and distributions into the future. The model results show that by the mid-century polar bear populations will likely be extirpated from their southernmost range in southeastern Canada, as well as from the Arctic regions bordering Alaska, Russia, and Europe. By late century, populations in east Greenland and the North Beaufort Sea will also likely be gone. And as stated before, these regions now support two-thirds of the worldwide population of polar bears, which is estimated at between 20,000 and 25,000 animals.

However, the models also predict a strong likelihood of polar bears surviving in the high Canadian Arctic, which may provide a source of animals to reestablish former ranges if the Arctic's sea ice environment is restored to present conditions.

Preliminary USGS analysis of other carbon loading scenarios indicate that less atmosphere carbon dioxide loading does not substantially change outcomes for polar bears through the mid-century but does result in less loss of sea ice and thus polar bear habitat by the end of the 21st Century.

At the USGS we recognize that the momentum of atmospheric greenhouse gas loading will challenge us with climate-related issues for at least the next 50 years. A better understanding of sea ice must be combined with an understanding of ecological response and adaptation to provide the best information to the decision-makers. We believe that outputs from coupled physical and biological forecasting approaches, as presented in our recent reports, will better inform decision-makers as they address climate adaptation. Such forecasting will require continued long-term monitoring of both sea ice and ecological response, focused studies of ecological processes in response to climate change, and the application of many new and emerging modeling approaches by science with many different specialties working together.

Thank you for the opportunity to present and address you today.

[The prepared statement of Dr. Haseltine follows:]

PREPARED STATEMENT OF SUSAN D. HASELTINE

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to participate in today's hearing to discuss emerging insights into the present and potential influences of climate variability and change on resources of interest to the American people. My name is Dr. Susan D. Haseltine, and I am the Associate Director for biology at the U.S. Geological Survey (USGS).

Global climate change is one of the most complex and formidable environmental challenges facing society today. While climate change is a natural, continuous Earth process, changes to the Earth's climate are related to human activities as well. Whether the causes are natural or from human influence, our focus is on understanding the impacts of climate change and the potential adaptive strategies for managing natural resources and ecosystems in the face of these changes.

Today, one need only turn to the Far North to witness the emerging signature of climate change. In Arctic and subarctic regions, the shrinking extent of and structural changes in sea ice and permafrost are a strong and visible signal of contemporary change in the Earth's climate system. Sea ice controls its associated ecological systems: From oceanographic patterns through the food chain to ice seals and polar bears, the Arctic marine world is tied to the dynamics of sea ice. I will focus my remarks on the realm of sea ice and recent publications by the USGS on this environment and its top predator, the polar bear. It should be recognized that this important work is part of a broad body of research carried out by other federal agencies and nations around the Arctic.

Data from the observed record document a recent history of change in Arctic sea ice. Observations from the available satellite record (1979–2007) show a decline of 10 percent per decade in the minimum annual Arctic sea ice extent (end of summer melt season). That decline is punctuated by this year's (2007) melt season, which reduced the minimum ice cover in the Arctic to just over four million square kilometers—as compared to the 7–8 million square kilometers observed at the beginning of the satellite record (1979–1980). The 2007 melt season thus reflects a roughly 40 percent reduction in ice extent from the 1979–2000 average. Even more significant is the degree to which the year 2007 surpassed the previous sea ice loss record of 2005—by about one million square kilometers.

Owing to the influential role that sea ice plays in Earth's climate system, numerous institutions and agencies worldwide (including the USGS) are conducting research to better understand the mechanisms and trajectory of sea ice change. The USGS is an active collaborator in this arena. Complementing the extensive amount of research supported by the National Science Foundation, NASA, NOAA and others, the USGS is helping to define an emerging understanding of the changes in ice age structure and the relationships of those trends to atmospheric circulation patterns, thermal forcing, and other controlling mechanisms. While rising Arctic air temperatures have certainly contributed to the loss of sea ice, several other factors have interacted to accelerate the loss. Changes in prevailing wind patterns (Maslanik et al., 2007) have caused much of the older and thicker sea ice to drift out of the Arctic Ocean (Rigor and Wallace, 2004; Belchansky et al., 2005), leaving behind a younger and thinner ice pack that is more vulnerable to the summer melt season. Concurrently, warmer ocean water has been entering the Arctic from both the Atlantic (Polyakov et al., 2007) and Pacific (Woodgate et al., 2006). A warmer Arctic Ocean further reduces the air-water temperature gradient, which suppresses winter ice growth (thickening) and renders it more susceptible to summer melt. And finally, onset of the Arctic melt season has been getting earlier (Belchansky et al., 2004; Stroeve et al., 2006). Earlier springs trigger an earlier start to an important positive feedback loop that begins when the bright surface of the ice darkens from the presence of melt ponds and open water, the darker surfaces warm faster because they absorb more solar radiation, and the warmth promotes more melt—and so on. To what degree natural climate variability has exacerbated the recent loss of sea ice is not well understood. However, there is growing scientific concern that the synergism of recent events, regardless of their origin, may have already pushed the Arctic past a threshold of cascading change (Lindsay and Zhang, 2005; Serreze and Francis, 2006).

The USGS is well poised to address the implications of ecological change in the Arctic by integrating its geophysical and biological expertise. Foremost among USGS biological studies in the Arctic is a long-term program of polar bear research. Owing to both the study's three-decade history and its longstanding collaboration with countries within the circumpolar distribution of polar bears, the USGS has accumulated a robust baseline of data crucial for assessment of population status in long-lived species such as the polar bear, for defining essential habitats, and for making projections of population status into the future. Nine recently released USGS reports build on this history of research and culminate in a new rangewide forecast of polar bear status under various projections of future climate change (Amstrup et al., 2007; Bergen et al., 2007; DeWeaver, 2007; Durner et al., 2007; Hunter et al., 2007; Obbard et al., 2007; Regehr et al., 2007a; Rode et al., 2007; Stirling et al., 2007).

Polar bears occur throughout portions of the Northern Hemisphere where the sea is ice-covered for all or much of the year and essentially derive their sustenance predominantly from ice seals such as ringed seals. The dependence of polar bears on hunting at the ice surface raises concern about the implications of sea ice loss. In the southern parts of the polar bear range, such as Hudson Bay, the sea ice melts entirely each summer and bears fast until the ice refreezes in autumn. However, warming temperatures have established a trend of earlier sea ice break-up, leaving the bears stranded on land and deprived of food for longer periods of time (Stirling and Parkinson, 2006). Recent data published by USGS and Canadian scientists document lower survival rates among young and sub-adult bears and establish scientific linkages between less ice cover, reduced survival, and population decline (Regehr et al., 2007b).

Similar to the early-warning signs seen in Western Hudson Bay, declines in body condition and survival are now documented for polar bears in Southern Hudson Bay and the Southern Beaufort Sea. These and other signs of stressed polar bear populations, together with the observed and forecasted declines in sea ice, prompted the USGS to assemble a team of polar bear, sea ice, and modeling experts aimed at reducing the uncertainties of observed and forecasted polar bear population status worldwide.

Because of the poor fossil record, we do not know how the forecasted distribution of bears compares to bear distribution at other times in the past when ice extent may have been restricted similarly to the models used for our forecasting.

The USGS assessed the pattern of observed changes in polar bear-sea ice habitat over the last two decades and forecasted the range of likely future habitat conditions out to the end of the century. Using long-term satellite tracking data from polar bear populations inhabiting the polar basin (Arctic Ocean), the USGS constructed habitat selection models using data collected during 1985–1995, before the sea ice changes had become pronounced. The resulting models demonstrated a strong preference for sea ice habitats that were near the periphery of the ice pack and over the shallow waters of the continental shelf. USGS habitat models for the 1996–2006 period found preferred habitats have already declined, especially in spring and summer with greatest losses in the Southern Beaufort, Chukchi, Barents, and Greenland seas (Durner et al., 2007).

The USGS then projected the range of likely future polar bear habitat conditions employing ten General Circulation Models (GCM) from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report. These models were selected on the basis of their ability to reasonably simulate the amount of observed sea ice cover in the Northern Hemisphere during the 20th century. It should be noted that the USGS used GCM projections derived entirely from the IPCC SRES–A1B greenhouse gas emissions scenario, which is also called the "business as usual" or "middle of the road" scenario, to develop sea ice projections. Preliminary USGS analyses of other emission scenarios (as corroborated in the IPCC Fourth Assessment Report) indicate that scenarios with less atmospheric carbon dioxide loading do not make a substantive change in polar bear outcomes through mid-century, but do result in less depletion of sea ice and thus polar bear habitat at the end of the century.

Projections from the 21st century-based models exacerbated the already observed habitat losses, and added losses throughout all regions bordering Russia. Annual habitat loss for the full basin is projected at more than 35 percent by the end of the century, with a summer loss of nearly 80 percent for the Alaska-Eurasia portions of the Basin. In contrast, polar bear habitats were projected to be relatively stable during the 21st century in the high-latitude regions along the northwestern Canadian Archipelago and northern Greenland. These results are consistent with the general observation that most GCMs project modest ice declines in winter but strong declines in summer, resulting in either ice-free summers or remnant summer ice at the northernmost latitudes of North America.

To forecast the status of polar bear populations worldwide during the 21st century requires not only information on likely future habitat condition (Durner et al., 2007) but also projections of population status based on present vital rates (Hunter et al., 2007). The USGS then developed a Bayesian network (BN) model structured around population stressors that could affect the factors considered in Endangered Species Act decisions (Amstrup et al., 2007). The BN model combined empirical data, interpretations of data, and professional knowledge into a probabilistic framework. The BN model incorporated information about annual and seasonal sea ice trends on populations as well as potential effects of other population stressors such as harvest, disease, predation, and effects of increasing human activity in the north due to ice retreat. Sensitivity analyses of the final model indicates that sea ice habitat loss is the overarching stressor responsible for model outcomes. Model results show that by mid-century, polar bear populations will likely be extirpated, or eliminated, from their southernmost range in southeastern Canada, as well as from regions of the polar basin bordering Alaska, Russia, and Europe. By late-century, populations in East Greenland and the Northern Beaufort Sea also have a high probability of extirpation. Model projections indicate a high likelihood of extirpation from regions of the Arctic that presently support two-thirds of the worldwide population of polar bears. These models, however, also predict a strong likelihood of remnant populations surviving in the high Arctic, which may provide a source of animals to reestablish former ranges if the Arctic's sea ice environment were to be restored by an ultimate slowing and reversal of global warming.

The USGS recognizes that the momentum of atmospheric greenhouse gas loading will challenge us with climate-related issues for at least the next 30–50 years. As such, we anticipate that the traditional approaches to natural resource conservation, public land management, and civil infrastructure planning may require accommodating and adapting to ecosystem change. The USGS conducts scientific research to understand the likely consequences of climate change, especially by studying how climate has changed in the past, then using the past to forecast responses to shifting climate conditions in the future, distinguishing between natural and human-influenced changes, and recognizing ecological and physical responses to changes in climate. These strengths allow the USGS to play a critical role in conducting climate change science across the Nation. A better understanding of sea ice must be combined with an understanding of ecological responses and adaptation. We believe that coupled physical-biological forecasting approaches, as presented in recent USGS polar bear reports, will better prepare decision-makers as they address climate adaptation. Such forecasting will require continued long-term monitoring, focused studies of process, and the application of new and emerging modeling approaches implemented through collaborative efforts among federal, academic and other partners.

Thank you for the opportunity to present this testimony. I am pleased to answer any questions you and other Members of the Committee might have.

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BIOGRAPHY FOR SUSAN D. HASELTINE

Career History and Highlights:

Dr. Haseltine has been with the USGS for more than 10 years. Before joining the USGS, she was Eastern Region Director for the former National Biological Service

(NBS), and she became Chief Scientist for Biology when the NBS joined the USGS in 1996.

Prior to joining the NBS, she managed the Refuges and Wildlife program in the Upper Midwest in Minneapolis, Minn., for the U.S. Fish and Wildlife Service (FWS) after serving as the Center Director for the Northern Prairie Wildlife Research Center in Jamestown, N. Dak. She joined the FWS as a researcher for the Patuxent Wildlife Research Center in Laurel, Md., and worked for more than a decade as a researcher and research manager before moving onto the Northern Prairie Wildlife Research Center.

Education:

Dr. Haseltine has a doctorate and Master's in zoology from Ohio State University and a Bachelor's in wildlife science from the University of Maine.

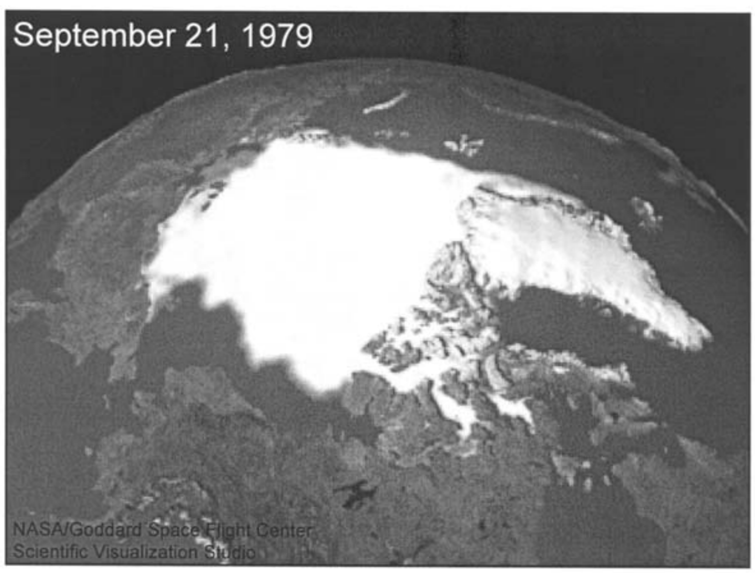
Chairman MILLER. Thank you, Dr. Haseltine. My great fear is that Mr. Rohrabacher is going to think that my indulgence that I am showing today on time limits for witnesses' testimony will also apply for time limits for Members' questioning.

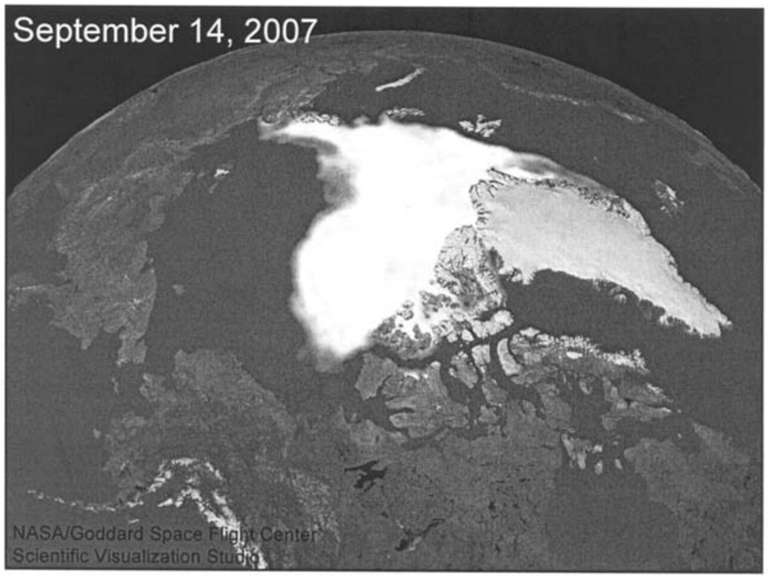
Ms. Siegel.

STATEMENT OF MS. KASSIE R. SIEGEL, DIRECTOR, CLIMATE, AIR AND ENERGY PROGRAM, CENTER FOR BIOLOGICAL DIVERSITY, JOSHUA TREE, CALIFORNIA

Ms. SIEGEL. Good morning, Mr. Chairman, and Members of the Committee. Thank you so much for the opportunity to testify.

Early next year the polar bear will likely be listed as threatened or endangered under the *Endangered Species Act.* While enormously significant both legally and politically, the listing of the polar bear will not in and of itself be enough to save the polar bear or its Arctic Sea ice habitat. Last month the Arctic Sea ice reached a stunning new minimum.





The sea ice looked like this in September 1979, and like this in September 2007. This is a loss of one million square miles off the average minimum sea ice extent of the past several centuries, and the melt is happening faster than forecast. This slide shows climate model predictions of sea ice extent and the dashed colored lines compared to actual observed sea ice extent in the heavy red line.

Sea ice in September 2007 was far below what any of the models predicted and perhaps most worrisome, there is less ice in the Arctic this year than more than half the models project for 2050.

The polar bear is a creature of the sea ice and needs the ice for all of its essential behaviors, including traveling and mating and hunting the primary prey of ice-dependent seals. Polar bears cannot hunt seals from land, and so tied to the ice are they that some mother polar bears even give birth to their cubs in snow dens like this one on top of the drifting ice.

Polar bears cannot survive without their Arctic sea ice habitat. The situation for polar bears in a rapidly warming Arctic is grim. Polar bears are drowning, resorting to cannibalism when they don't have access to their usual food sources, and starving.

This photograph was taken in Quebec, Canada, last month. This bear is in the final stages of starvation. While we cannot say for sure that this bear died as a direct result of global warming, we do know that global warming is increasing and will continue to increase the number of bears that suffer this fate. But we also know that it is not too late to do something about it. Motivated by the need to do so, the Center for Biological Diversity filed a petition to list the polar bear under the *Endangered Species Act* in February 2005. The listing process has already benefited the species by raising awareness of its plight and leading to new information, such as the U.S. study which predicts the extinction of two-thirds of the world's polar bears by 2050 which was conducted in support of the listing process.

The Arctic has reached a critical threshold, and our window to act, like the ice itself, is melting rapidly away; but it is not too late. The grim projections from the USGS are based on the A1B IPCC Emission Scenario in which CO_2 concentrations reached 717 parts per million by the end of this century. We know that business as usual cannot continue, and we must limit CO_2 concentrations to below 450 parts per million. We need deep, rapid, and mandatory reductions in CO_2 to save the polar bear. But the Arctic has advanced so far toward the tipping point that CO_2 reductions are now necessary but not sufficient to save polar bears. Anything else we do may be futile if we don't address this most important of greenhouse gases. CO_2 has a long atmospheric lifetime, so the benefits of CO_2 reductions today will take a long time to be fully felt. We need a way to buy ourselves some time. Fortunately, we have an opportunity to do just that by addressing methane and black carbon emissions, both pollutants with short atmospheric lifetimes and a very high warming impact in the Arctic. By attacking methane and black carbon emissions, we can have a short-term benefit in the Arctic, and we can provide ourselves with the last and golden opportunity to give polar bears back their future.

Methane is a globally well-mixed gas, 21 times more powerful than CO_2 but stays in the atmosphere for about 12 years. Methane also leads to higher levels of tropospheric ozone, which has a high warming impact in the Arctic where it absorbs light energy reflected off the snow and ice. So by reducing methane we can also reduce ozone levels in the Arctic and provide a double benefit to the region in the short-term.

Further good news is that there are enormous amounts of cost-positive and no-cost methane reductions sitting on the table today. We have fantastic opportunities to capture methane from landfills and from livestock operations and use it to generate energy and to reduce methane losses from natural gas systems, just to name a few. According to conservative projections from the U.S. EPA, conservative estimates, we can reduce nearly 70 million metric tons of CO_2 equivalent methane emissions in the U.S. by 2010 at a cost benefit or no cost. That is the equivalent of getting paid to take 12 million cars off the road, and we can do so much more at low cost. But voluntary measures and the market have not provided the so-called no regrets emission reductions. We desperately need Congressional action.

Black carbon or soot is emitted from the inefficient burning of fossil fuels, biofuels, and biomass. We have opportunities to reduce soot from sources such as diesel fuel and coal-fired power plants. Soot remains in the atmosphere for only about five days but has an extraordinarily powerful warming impact of about 500 times that of CO_2 over a 100-year period. It is particularly important to address within Arctic sources like diesel generators and ship engines.

The rapid melting of the Arctic is the Earth's early warning system, and yet like beachgoers chasing the receding waters immediately prior to a tsunami to gather up the exposed shellfish, nations and industry are racing to the newly ice-free areas to stake claims for fossil fuel development and shipping routes that would commit us further down the path to climate catastrophe.

To save the polar bear, we must not only find courage to reduce greenhouse gas pollution but also to protect the Arctic from further industrial exploitation. We believe that Congress should act immediately to slash methane and black carbon emissions. Methane emissions from landfills, livestock operations, natural gas systems, and other sources should be strictly limited. Black carbon emissions from the use of diesel fuel and coal must also be addressed. These measures will also greatly benefit our economy and public health. We also believe Congress should enact a moratorium on new fossil fuel leasing and development in the Arctic where these activities both directly impact the species most at risk for global warming and also contribute substantially to greenhouse gas emissions.

If we truly act with speed and determination, it is not too late to save the polar bear, to save the entire productive Arctic ecosystem, and to avoid the worst impacts of global warming for ourselves.

Thank you.

[The prepared statement of Ms. Siegel follows:]

PREPARED STATEMENT OF KASSIE R. SIEGEL

Not too Late to Save the Polar Bear: A Rapid Action Plan to Address the Arctic Meltdown

In early 2008, the polar bear will likely be formally declared "threatened" or "endangered" under the *Endangered Species Act.* But listing of the polar bear under the *Endangered Species Act,* while hugely significant both legally and politically, will not in and of itself save the polar bear or its Arctic sea-ice habitat. In September 2007, the same month that Arctic sea ice reached a new record minimum extent, government scientists predicted the polar bear would be extinct in Alaska by 2050 if current greenhouse gas emission trends continue.

Predictions of polar bear extinction by 2050 may be optimistic. Recent reports from scientists indicate that global warming impacts are occurring earlier and more intensely than previously projected. Nowhere is this more apparent than in the Arctic where, in 2007, sea-ice extent shrank to a record one million square miles below the average summer sea-ice extent of the past several decades, reaching levels not predicted to occur until mid-century. Not only does the impending loss of Arctic sea ice mean the loss of an entire ecosystem, it will also greatly amplify warming impacts on a global level due to the greater absorption of the sun's energy by open water compared to the reflective ice.

The rapid melting of the Arctic should be seen as an early warning of the broader climate crises to come if the U.S. and the world do not respond to global warming with the necessary urgency. Instead, like beach-goers chasing the receding waters immediately prior to a tsunami to gather up the exposed shellfish, nations and industry are racing to the newly ice-free areas to stake claims for fossil fuels and shipping routes that would lead us further down the path to climate catastrophe.

The situation in the Arctic has reached a critical threshold. But with immediate action it is still possible to slow the melting of the Arctic. In addition to broader local, national, and international efforts to reduce U.S. and global carbon dioxide (CO_2) emissions, saving the Arctic requires prompt reductions of other greenhouse gases, along with specific efforts to address direct threats to the region from industrial activities such as oil development and shipping. Reducing emissions of methane and black carbon, which both have short atmospheric lifetimes and a large warming impact on the Arctic, is a critical component of any effective action plan. Immediate methane and black carbon emissions reductions can buy the world a little more time to achieve the deep reductions in CO_2 emissions that are necessary to protect the far north. But the window of opportunity to act, like the ice, is shrinking rapidly.

I. The Polar Bear, Global Warming, and the Endangered Species Act

Polar bears are completely dependent upon Arctic sea-ice habitat for survival. Polar bears need sea ice as a platform from which to hunt ringed seals and other prey, to make seasonal migrations between the sea ice and their terrestrial denning areas, and for other essential behaviors such as mating. Unfortunately, the polar bear's sea-ice habitat is literally melting away.

Global warming is impacting the Arctic earlier and more intensely than any other area of the planet. In parts of Alaska and western Canada, winter temperatures have increased by as much as 3.5°C in the past 30 years (Rozenzweig et al., 2007). Over the next 100 years, under a moderate emissions scenario, annual average temperatures in the Arctic are projected to rise an additional 3–5°C over land and up to 7°C over the oceans (Meehl et al., 2007).

This rapid observed and projected warming is reflected in the devastating melt of the Arctic sea ice, which is highly sensitive to temperature changes. Summer sea-ice extent reached an unpredicted and utterly stunning new record minimum in 2007 (NSIDC, 2007a,b; Figures 1, 2). At 1.63 million square miles, the minimum sea-ice extent on September 16, 2007 was about one million square miles[1] below the average minimum sea ice extent between 1979 and 2000 (NSIDC, 2007a). The 2007 minimum was lower than the sea-ice extent most climate models predict would not

[1] One million square miles is equal to about the area of Alaska and Texas combined.

be reached until 2050 or later. Leading sea ice researchers now believe that the Arctic could be completely ice free in the summer as early as 2030 (NSIDC, 2007b).

Climate change in the Arctic has reached a critical threshold, and the future of the ice-dependent polar bear is grim. Even short of complete disappearance of sea ice, projected impacts to polar bears from global warming will affect virtually every aspect of the species' existence. These impacts include a reduction in the hunting season caused by delayed ice formation and earlier break-up, resulting in reduced fat stores, reduced body condition, and subsequent reduced survival and reproduction; increased distances between the ice edge and land, making it more difficult for bears to reach preferred denning areas; increased energetic costs of traveling farther between ice and land and through fragmented sea ice; and reduction in ice-dependent prey such as ringed seals and bearded seals (Derocher et al., 2004). Global warming will also increase the frequency of human/bear interactions, as greater portions of the Arctic become more accessible to people and as polar bears are forced to spend more time on land waiting for ice formation (Derocher et al., 2004). More human/bear interactions will almost certainly lead to increased polar bear mortality.

Five of the world's polar bear populations are now classified as declining, with a 22 percent decline—from 1,194 bears in 1987 to 935 bears in 2004—in Canada's Western Hudson Bay polar bear population (Aars et al., 2006). Recently, reports of polar bear drownings, cannibalism, and starvation have increased (Amstrup et al., 2006; Regehr et al., 2006; Aars et al., 2006). With the amount, location, and access to their ice-dependent seal prey changing rapidly, polar bears are increasingly vulnerable to starvation.

Figure 1 shows a polar bear in the final stages of starvation. This photo was taken on September 4, 2007 on the Caniapiscau River in Canada, 160 km inland from Ungava Bay. While we cannot say for sure that this bear starved to death as a direct result of global warming, as we do not know the bear's history or origin, we do know that global warming will increase the number of bears that suffer this fate. We also know that we have the power to limit the number of polar bears that starve, drown, and resort to cannibalism, and to save the species from extinction by immediately reducing greenhouse gas pollution.

The Center for Biological Diversity submitted a Petition to the Secretary of the Interior and U.S. Fish and Wildlife Service to list the polar bear under the *Endangered Species Act* due to global warming on February 16, 2005, motivated by the urgent need to reduce greenhouse gas pollution and otherwise protect the species. The *Endangered Species Act* is our nation's safety net for plants and animals on the brink of extinction, and our strongest and best law for the protection of imperiled wildlife. The *Endangered Species Act* listing process has already benefited the polar bear, will provide additional protections once the species is formally listed, and is a key component of saving the species.

Critically important for the polar bear and any other species threatened by global warming, the *Endangered Species Act* requires all listing decisions be made "solely" on the basis of the "best scientific. . .data available." 16 U.S.C. § 1533(b)(1)(A). A decision not to list a petitioned species is subject to judicial review. It is this "best available science" standard that provides a vehicle through the petitioning process to force federal agencies to squarely address the science of global warming. Moreover, once the *Endangered Species Act* listing process is initiated, strict timelines apply, with an initial finding due within 90 days of the petition, a proposed rule within 12 months of the petition if the Fish and Wildlife Service finds that the species meets the criteria for listing, and a final listing determination within a year from the proposed rule. Species do not receive any regulatory protection under the Act until they are officially listed as threatened or endangered.

A series of administrative and legal events in the listing process have greatly increased public awareness of the polar bear's plight. In December 2005, ten months after the Petition was filed, the Center for Biological Diversity, joined by NRDC and Greenpeace, sued the Department of Interior for failing to issue an initial finding on the Petition. In response, a positive initial finding was issued in February, 2006, initiating both a public comment period and full status review for the species. The deadline for the second required finding on the Petition, due within 12 months of receipt of the petition, was only one week away at the time the first finding was made. The lawsuit was ultimately settled with a court-ordered consent decree setting a deadline of December 27, 2006 for the Fish and Wildlife Service to make the second determination.

On December 27, 2006, Secretary of Interior Dirk Kempthorne announced that listing of the polar bear is warranted and that the Fish and Wildlife Service would be publishing a proposed listing rule. The proposal to list the polar bear was greeted by worldwide media attention, resulting in over 250 television stories, more than 1000 print stories and over 240 editorials. Over 600,000 comments were submitted during the public comment periods on the proposal. The final listing determination is due on January 9, 2008.

Once the polar bear is listed, the *Endangered Species Act* requires the Fish and Wildlife Service to identify and designate critical habitat, convene a recovery team and develop and implement a recovery plan. Additionally, the requirement for federal agencies to avoid jeopardizing the species, and a prohibition against unpermitted take (harm and harassment), will take effect. These regulatory protections should provide substantial benefit to the polar bear (Cummings and Siegel, 2007). While the polar bear has yet to receive any actual legal protection as a result of the Endangered Species Act listing process, the process has already played an important role by being a catalyst to focus significant new scientific, public, and political attention on the problem of the melting Arctic and global warming.

The listing process has prompted research and analysis on the future of the polar bear, its sea-ice habitat, and the Arctic more generally. Most important among these research efforts are the recent reports released by the Department of Interior's U.S. Geological Survey (USGS). The Fish and Wildlife Service asked the USGS to do the following in support of the listing process: (1) develop population projections for the Southern Beaufort Sea polar bear population and analyze existing data on two polar bear populations in Canada; (2) evaluate northern hemisphere sea-ice projections, as they relate to polar bear sea-ice habitats and potential future distribution of polar bears; and (3) model future range-wide polar bear populations by developing a synthesis of the range of likely numerical and spatial responses to sea-ice projections. The USGS produced nine administrative reports addressing these questions and in doing so significantly advanced the understanding of sea-ice loss and its implications for polar bears.

The USGS conducted polar bear population modeling based on 10 climate models that most accurately simulate future ice conditions. The USGS used the Intergovernmental Panel on Climate Change ("IPCC") A1B "business as usual" scenario of future emissions to run the climate models. In the A1B scenario, atmospheric carbon dioxide concentrations reach 717 parts per million by 2100. These sea-ice projections were used in a number of applications, including in a Bayesian Network model developed by the USGS to most accurately project the future range-wide status of the polar bear. The results are disturbing.

The USGS (Amstrup et al., 2007) project that two-thirds of the world's polar bears will be extinct by 2050, including all of the bears in Alaska. The "good news" is that polar bears may survive in the high Canadian Archipelago and portions of Northwest Greenland through the end of this century. However, their extinction risk is still extremely high: over 40 percent in the Archipelago and over 70 percent in Northwest Greenland (Amstrup et al., 2007:Table 8).

Moreover, the USGS emphasizes repeatedly that because all of the available climate models have to date underestimated the actual observed sea-ice loss, the assessment of risk to the polar bear may be conservative. Perhaps most worrisome is the observation that part of an area in the Canadian Archipelago expected to provide an icy refuge for the polar bear in 2100 lost its ice in the summer of 2007.

The USGS projections of polar bear extinction risk are based on the IPCC A1B "business as usual" scenario, near the center of the distribution of all IPCC scenarios, in which atmospheric carbon dioxide concentrations reach 717 parts per million by 2100 (Nakicenovic, 2000). If future emissions meet or exceed the A1B scenario, the eventual extinction of polar bears is virtually guaranteed, as extinction risk will exceed 40 percent even in the high Canadian Archipelago in 2100, and warming will continue after 2100. The USGS reports, however, do not address the question of how much polar bear extinction risk can be reduced if greenhouse gas emissions are curtailed significantly below those assumed in the A1B scenario. Decreasing greenhouse gas emissions substantially can limit the Arctic sea-ice melt and therefore lower extinction risk for the polar bear.

While not explicitly making an *Endangered Species Act* listing recommendation, the information contained in the USGS reports definitively answers the question of whether the polar bear is in fact in danger of extinction and therefore warrants the protections of the Act with an emphatic and distressing "yes." Any decision by the Fish and Wildlife Service to deny or delay listing would be patently unlawful. The point of the *Endangered Species Act,* however, is not simply to add species to the list, but to actually save them. If "business as usual" emissions trends continue, the polar bear will be driven extinct irrespective of *Endangered Species Act* listing or any other management actions. Business as usual is simply no longer an option. If the polar bear is to have a future, we as a nation and as a global community must immediately begin implementing deep greenhouse gas emissions reductions as well as change our management paradigms to reflect the new realities presented by a warming Arctic. The remainder of this paper sets forth an action plan to do so.

II. Reducing Greenhouse Pollutants Rapidly Enough to Address Arctic Melting

The essential first component of an action plan to save the polar bear is a mandatory reduction in CO_2 pollution. Beginning CO_2 reductions immediately and eventually reducing them to a small fraction of current levels such that atmospheric CO_2 concentrations never rise above about 450 ppm is essential to saving polar bears. But the Arctic has reached such a critical threshold that CO_2 reductions alone, even if undertaken immediately and with determination, will almost certainly not be enough to slow and reverse the warming and melting trend. This is because CO_2, once emitted, tends to remain in the atmosphere for centuries (Archer, 2005), and therefore the benefits of reductions today will not be fully felt for some time.

Our window of opportunity to save polar bears relates to the fact that the warming impact of "non-CO_2" pollutants including methane, tropospheric ozone, and black carbon (soot) is larger in the Arctic than it is globally. The non-CO_2 pollutants are responsible for at least half of the warming in the Arctic (Hansen et al., 2007), as opposed to about 30 percent globally (Forster and Ramaswamy, 2007; Figure 4). Black carbon has a disproportionately large warming impact in the Arctic, and both black carbon and methane have much shorter atmospheric lifetimes than CO_2. This means that immediately reducing these pollutants can buy some desperately needed time and presents our best opportunity for slowing and reversing the Arctic melting before it is too late.[2]

Fortunately, there are many feasible reduction measures available today for these pollutants, with literally hundreds of millions of metric tons of CO_2eq "no-cost" reductions on the table, including many that could be undertaken at a net economic benefit. (Tables 1–4). According to conservative projections by the U.S. EPA, about 500 MtCO_2eq of global methane emissions reductions could be achieved globally by 2020 at a cost benefit or no cost (EPA, 2006; Table 4, Figure 7). Nearly 70 MtCO_2eq of these available reductions are in the United States (EPA, 2006; Table 2, Figure 6). The EPA estimates total technically feasible methane reductions for 2020 at over 2400 MtCO_2eq globally and nearly 280 MtCO_2eq in the U.S., many of which can be achieved at low cost (EPA, 2006; Tables 2 and 4; Figures 6,7).

Reductions in CO_2, methane and black carbon will have major public health benefits as well. Many of the measures necessary to reduce global warming pollution, including increasing energy efficiency, increasing the use of renewable energy and phasing out fossil fuels, and ultimately changing our land use, transportation, and consumption patterns, will improve our quality of life, improve our economy, and make the world a healthier, safer, and more equitable place. Congress should act immediately to explicitly cap and then rapidly reduce not only CO_2, but also the non-CO_2 pollutants.

Below we review necessary reductions in greenhouse gas pollutants and opportunities for targeted actions to protect the Arctic. Further detail on mitigation strategies for methane, black carbon, nitrous oxide, and the high global warming potential gases is found in Appendix A.

A. Carbon Dioxide

Because CO_2 is the most important greenhouse gas, the rapid and mandatory reduction of CO_2 emissions is the backbone of any plan to slow the Arctic melt (Quinn et al., 2007) and thus save the polar bear. If carbon dioxide concentrations are not controlled soon, polar bears will have little chance of future survival regardless of what else is done. Leading scientists warn that CO_2 concentrations must be kept below about 450 ppm in order to keep the climate system within the range of variability of the past 650,000 years and minimize the chance of triggering major climate feedbacks, such as a large scale release of methane from the Arctic permafrost, that would greatly amplify anthropogenic warming (Hansen et al., 2006; Hansen et al., 2007). They further warn that the 450 ppm limit may need to be reduced further in the future (Hansen and Sato, in prep.). Keeping global CO_2 concentrations below 450 parts per million would require the U.S. to begin reducing its emissions quickly, and to reduce them to 80 percent or more below 1990 levels by the middle of this century.

It is essential that the U.S. rejoin the U.N. Framework Convention on Climate Change negotiating process and participate in global solutions. The Bush Administration has been blocking progress at the international level for over six years, and the U.S. and Australia are the only developed countries that have refused to ratify the Kyoto Protocol, the first mandatory greenhouse gas reduction agreement under

[2] For ease of comparison, the volume of each pollutant is expressed as its "carbon dioxide equivalent" in millions of metric tons. Thus, one million metric tons of methane is equivalent to 21 million metric tons of CO_2 equivalent (MtCO_2eq).

the Framework Convention process. The U.S. should commit to meeting its Kyoto target of reducing its emissions to seven percent below 1990 levels between 2008 and 2012, and join negotiations for much deeper emissions reductions after 2012.

Congress must pass legislation that caps and rapidly reduces greenhouse gas pollution with mandatory measures. Fortunately, there are several bills introduced that if passed, enacted, and fully enforced, would result in emissions dropping to approximately 80 percent below 1990 levels by 2050, including the *Safe Climate Act* (H.R. 1590, Waxman) and the *Global Warming Pollution Reduction Act* (S. 309, Sanders). The survival of the Arctic sea ice and the polar bear depends upon one of these bills or something similar becoming law soon.

However, the Arctic melt has advanced so far towards a tipping point that CO_2 reductions are necessary, but not sufficient, to save polar bears. In addition to current legislative proposals, Congress must target other pollutants, including methane and black carbon, to provide the necessary short-term climate benefit to the Arctic.

B. Methane

Methane is the most important of the non-CO_2 pollutants, with a global warming potential 21 times greater than carbon dioxide, and an atmospheric lifetime of 12 years (Forster and Ramaswamy, 2007). Methane constitutes approximately 20 percent of the anthropogenic greenhouse effect globally, the largest contribution of the non-CO_2 gases. As a precursor to tropospheric ozone, methane emissions have an even more powerful impact on climate. In the Arctic this impact is strongest in winter months, which can result in an acceleration of the onset of spring melt (Shindell, 2007). Tropospheric ozone, unlike other greenhouse gases, absorbs both infrared radiation and shortwave radiation (visible light). Thus, tropospheric ozone is a particularly powerful greenhouse gas over highly reflective surfaces like the Arctic, because it traps shortwave radiation both as it enters the Earth's atmosphere from the sun and when it is reflected back out again by snow and ice. Reducing global methane emissions will reduce ozone concentrations in the Arctic, providing a double benefit to the region.

According to conservative projections by the U.S. EPA, about 500 $MtCO_2eq$ of methane emissions reductions could be achieved globally by 2020 at a cost benefit or at no cost (EPA, 2006; Table 4, Figure 7). That is the equivalent of taking almost 90 million cars and light trucks off the road. Nearly 70 $MtCO_2eq$ of these available reductions are in the United States (EPA, 2006; Table 2, Figure 6). That is the equivalent of taking over 12 million cars and light trucks off the road. The EPA estimates total technically feasible methane reductions for 2020 at over 2400 $MtCO_2eq$ globally and nearly 280 $MtCO_2eq$ in the U.S., many of which can be achieved at low cost (EPA, 2006; Tables 2 and 4; Figures 6, 7).

The EPA's cost projections are conservative for a number of reasons, including the use of a 10 percent discount rate. Using a lower discount rate would result in additional cost benefit or no-cost reductions. Moreover, the EPA analysis does not account for the value of significant air quality and health benefits that would accompany methane reductions. West et al. (2006) found that reducing global methane emissions by 20 percent would save 370,000 lives between 2010 and 2030, due to the reduction in ozone related cardiovascular, respiratory, and other health impacts. Methane reductions would also decrease ozone-related damage to ecosystems and agricultural crops (West et al., 2006). Methane is the primary component of natural gas, and many abatement options include the use of captured methane to generate energy. The benefits of displacing other fossil fuel energy sources with captured methane are also not captured in the EPA (2006) analysis.

While EPA (2006) may underestimate available no-cost and low-cost methane (and other non-CO_2 gas) mitigation options, even this conservative analysis shows the enormous opportunities available to us today (Tables 1–4; Figures 6–7). These reductions can be achieved with currently available technology, as described in Appendix A. Moreover, mandatory greenhouse gas regulation will speed the development and deployment of new technology and mitigation options, making much deeper reductions feasible in the very near future.

C. Black Carbon or Soot

Black carbon, or soot, consists of particles or aerosols released through the inefficient burning of fossil fuels, biofuels, and biomass (Quinn et al., 2007). Black carbon warms the atmosphere, but it is a solid, not a gas. Unlike greenhouse gases, which warm the atmosphere by absorbing long-wave infra-red radiation, soot has a warming impact because it absorbs short-wave radiation, or visible light (Chameides and Bergin, 2002). Black carbon is an extremely powerful greenhouse pollutant. Scientists have described the average global warming potential of black carbon as about 500 times that of carbon dioxide over a 100 year period (Hansen et al., 2007;

see also Reddy and Boucher, 2007). This powerful warming impact is remarkable given that black carbon remains in the atmosphere for only about four to seven days, with a mean residence time of 5.3 days (Reddy and Boucher, 2007).

Black carbon contributes to Arctic warming through the formation of "Arctic haze" and through deposition on snow and ice which increases heat absorption (Quinn et al., 2007; Reddy and Boucher, 2007). Arctic haze results from a number of aerosols in addition to black carbon, including sulfate and nitrate (Quinn et al., 2007). The effects of Arctic haze may be to either increase or decrease warming, but when the haze contains high amounts of soot, it absorbs incoming solar radiation and leads to heating (Quinn et al., 2007).

Soot also contributes to heating when it is deposited on snow because it reduces reflectivity of the white snow and instead tends to absorb radiation. A recent study indicates that the direct warming effect of black carbon on snow can be three times as strong as that due to carbon dioxide during springtime in the Arctic (Flanner, 2007). Black carbon emissions that occur in or near the Arctic contribute the most to the melting of the far north (Reddy and Boucher, 2007; Quinn et al., 2007).

Reductions in black carbon therefore provide an extremely important opportunity to slow Arctic warming in the short-term, and mitigation strategies should focus on within-Arctic sources and northern hemisphere sources that are transported by air currents most efficiently to the Arctic. Conversely, allowing black carbon emissions to increase in the Arctic as the result of increased shipping or industrial activity, will accelerate loss of the seasonal sea ice and extinction of the polar bear. Black carbon reductions will also provide air quality and human health benefits.

Despite its significance to global climate change and to the Arctic in particular, black carbon has not been addressed by the major reports on non-CO_2 gas mitigation, nor is it addressed in current global warming bills in the 110th Congress. Black carbon reductions are an essential part of saving the Arctic sea ice and the polar bear, and should be addressed by Congress in this session. Abatement opportunities are discussed further in Appendix A.

D. Other Non-CO_2 Pollutants

Nitrous oxide and the high global warming potential gases do not have the same heightened impacts in the Arctic as methane and black carbon. Nevertheless, because these gases have high global warming potentials and long atmospheric lifetimes, and because there are many readily available mitigation measures to reduce them, they present important opportunities for reducing global warming overall and are therefore an important part of saving the Arctic and the polar bear.

Nitrous oxide has a global warming potential 310 times that of carbon dioxide and an atmospheric lifetime of approximately 114 years (Forster and Ramaswamy, 2007). It constitutes the second largest proportion of anthropogenic non-CO_2 gases at seven percent. The main sources of nitrous oxide emissions are agriculture, wastewater, fossil fuel combustion, and industrial adipic and nitric acid production.

High global warming potential (High-GWP) gases fall into three broad categories: hydrofluorocarbons (HFCs), perfluorcarbons (PFCs), and sulfur hexafluoride (SF_6). Hydrofluorocarbons were developed to replace ozone-depleting substances used in refrigeration and air conditioning systems, solvents, aerosols, foam production, and fire extinguishing. HFCs have global warming potentials between 140 and 11,700 times that of carbon dioxide, and their atmospheric lifetimes range from one year to 260 years (EPA, 2006).

Perfluorocarbons are emitted during aluminum production and semiconductor manufacture (EPA, 2006). Their global warming potential ranges from 6,500 to 9,200 times that of carbon dioxide. In addition, they have extremely long atmospheric lifetimes (e.g., 10,000 and 50,000 years for two common PFCs).

The highest global warming potential exists in sulfur hexafluoride at 23,900 times that of carbon dioxide. Sulfur hexafluoride remains in the atmosphere for 3,200 years. Sulfur hexafluoride is used: (1) for insulation and current interruption in electrical power transmission and distribution; (2) during semiconductor manufacture; and (3) to protect against burning in the magnesium industry.

Further information on abatement options for these pollutants is found in Appendix A.

E. Reduced CO_2 and Non-CO_2 Pollutants and the Future Arctic

As discussed above, keeping CO_2 levels below 450 ppm and substantially reducing all non-CO_2 forcings is essential if we are to keep global temperatures from rising more than 1°C above 2000 levels and thereby minimize the risk of triggering major climate feedbacks which would lead to significantly elevated warming (Hansen et al., 2006). Achieving such greenhouse gas reductions is therefore critical if we are to not only prevent the extinction of the polar bear, but avoid the most catastrophic impacts of global warming. But even under such a scenario, the Arctic will still undergo significant additional warming with the concomitant additional loss of sea ice. Approximately 0.6°C of additional warming is already in the pipeline due to the excess energy in the Earth's climate system from past greenhouse gas emissions (Hansen et al., 2005; Alley et al., 2007). Additional warming will follow rising CO_2 levels even if we keep such levels below 450 ppm. As with the warming observed to date, the Arctic will continue to warm more rapidly than the global average. Substantial additional reduction of Arctic sea ice over the course of this century is therefore likely unavoidable. For the polar bear, things are going to get much worse before they begin to get better.

As grim as the outlook for the polar bear is, it is not hopeless. Unlike the terrestrial ice-sheets of Greenland, the melting of which may become irreversible on human-relevant timeframes, the Arctic sea ice, portions of which melt and reform every year, may be capable of relatively rapid recovery following climate stabilization. Assuming greenhouse emission targets can be met, the climate can be stabilized, and with subsequent reductions in atmospheric CO_2 levels, the Arctic sea ice can recover to levels supporting long-term viable populations of polar bears and other ice-dependant species. The key to polar bear persistence then, is weathering the very bumpy ride through the next half-century. To shepherd the polar bear through the ensuing decades, we must reduce all other stressors on the species and its habitat and tailor national and international management of the sensitive Arctic ecosystem to the new reality of a rapidly changing Arctic.

III. A New Management Paradigm for a Warming Arctic

As the September, 2007 sea-ice minimum starkly illustrates, global warming in the Arctic is not a future problem that can be shunted off to the next generation of decision-makers. It has arrived and is already leaving starving and drowning polar bears, melting permafrost and coastal erosion in its wake. While implementing the rapid reductions in emissions of both CO_2 and non-CO_2 pollutants described above is essential to avoid runaway future warming in the Arctic and elsewhere, if polar bears are to survive we also have to adapt policy measures to the warming that has already occurred, that is unavoidably in the pipeline, and that will inevitably come with projected rising atmospheric CO_2 levels. The Arctic of 2007 is very different than the Arctic of just a decade ago; the Arctic of 2050 will be virtually unrecognizable.

While the ongoing changes in the Arctic are now readily apparent, for the most part, U.S. federal agencies have utterly failed to incorporate this new reality into their decision-making affecting the Arctic. With the possible exception of the Department of Defense (*see, e.g.,* ONR, 2001), federal agencies are making planning decisions and issuing permits, authorizations and leases in and affecting the Arctic with a near-total disregard for the rapidly changing conditions in the region. This is leading to uninformed and unwise decision-making negatively affecting the polar bear and the entire Arctic ecosystem.

If U.S. agencies have been slow to recognize and respond to new conditions as the sea ice recedes, the rest of the world has been quick to claim the spoils of a warming Arctic. Russia, Norway and Denmark have all recently staked competing territorial claims to portions of the oil-rich Arctic seabed while Canada has asserted sovereignty over the increasingly ice-free Northwest Passage. Similarly, the specter of a seasonally ice-free Arctic carries with it the likelihood of greatly increased shipping in the region.

Many of these elements of a changing Arctic carry a double threat to the polar bear. Increased oil and gas development in the Arctic threatens not just to degrade important polar bear habitat, but will also lead to further fossil fuel commitments, making emissions reduction targets all the more difficult to reach. Increased shipping in the Arctic carries increased risks of oil spills and further disruptions of the polar bear's habitat, but also, perhaps more importantly, would lead to a substantial injection of additional black carbon directly where it would do the most damage to the Arctic climate. Finally, territorial disputes in the Arctic will lead to an increased military presence in the Arctic leading to disruption and pollution from vessels and aircraft as well as increasingly frequent polar bear/human interactions—encounters that the polar bears almost always lose.

If we are to respond to the warming Arctic in a manner compatible with the long-term survival of the polar bear, we must directly confront the changes taking place in the region. Federal agencies must incorporate the best available information about global warming and its impacts on the Arctic into all decisions directly or indirectly affecting the Arctic. We must also reduce direct impacts on polar bears and their habitat from shipping and industrial activities through such measures as a moratorium on the expansion of such activities in areas subject to U.S. control. Finally, because protecting the polar bear and the Arctic is only possible with the cooperation of not only all Arctic nations, but with the global community more broadly, we should initiate and engage in proactive multilateral efforts to protect the Arctic and its resources so they remain largely unspoiled for future generations in a manner similar to what has been accomplished under the Antarctic Treaty. Each of these measures is described in more detail below. All are necessary if polar bears are to survive in the very different Arctic we have given them.

A. Incorporate Global Warming into Federal Agency Decisions

Congressional action and new laws explicitly capping and reducing CO_2 and non-CO_2 pollutants are clearly necessary if we are to slow and ultimately reverse global warming and save the Arctic and the polar bear. Nevertheless, existing law allows, and in some cases requires, the executive branch to take significant action to address the current and future impacts of global warming on vulnerable human landscapes, natural ecosystems, plants and wildlife. Use of this authority will benefit all imperiled species, including the polar bear. Unfortunately, such statutory mandates have largely been underutilized, ignored, or explicitly rejected by the current administration.

Existing laws governing federal agencies that relate to global warming and the Arctic fall into three broad categories: laws requiring the compilation and analysis of information relevant to decision-makers; laws requiring the contribution of a given agency decision or action to greenhouse gas emissions and global warming be analyzed and in some cases mitigated; and laws requiring the changing status of species and resources in a warming climate be properly considered in decision-making. Several laws address more than one of these categories. Examples of each, relevant to the polar bear, which the administration has ignored or underutilized are briefly discussed below.

Information-generating statutes:

The Global Change Research Act (GCRA) requires the administration to provide to Congress and agencies an assessment of the trends and effects of global climate change on the United States, to be updated every four years. 15 U.S.C. Sec. 2936(2)–(3). The last such assessment was prepared in 2000. The administration is under court order to prepare a new assessment by May 2008, as the result of a lawsuit brought by the Center for Biological Diversity, Friends of the Earth and Greenpeace.

The *Marine Mammal Protection Act* (MMPA) requires regularly updated stock assessment reports that summarize the current status of all marine mammals subject to U.S. jurisdiction. 16 U.S.C. § 1361 *et seq.* Updated stock assessments for polar bears and walrus are two years overdue. Stock assessments for ice-dependant seals relied upon by polar bears for food, while regularly updated, do not incorporate recent information on global warming and sea-ice declines.

Analysis of greenhouse gas emissions from federal actions:

The Outer Continental Shelf Lands Act (OCSLA) governs the leasing of tracts for offshore oil development in federal waters, including those areas of the Beaufort and Chukchi seas utilized by polar bears. In approving the 2007–2012 Program covering all offshore leasing in the U.S., the Secretary of Interior refused to quantify the greenhouse gas emissions from the oil and gas expected to be produced under the program and failed to monetize CO_2 and non-CO_2 pollutants in calculating the economic costs and benefits of the program.

The National Environmental Policy Act (NEPA) requires the preparation of an environmental impact statement analyzing all significant impacts of proposed federal actions. Few NEPA documents for significant greenhouse gas generating projects prepared to date analyze the impacts of such emissions. None that we are aware of analyze the impacts of greenhouse gas or black carbon emissions on Arctic warming or the polar bear.

The *Endangered Species Act* (ESA) requires each federal agency to ensure through consultation with the Fish and Wildlife Service that any federal action does not jeopardize the continued existence of any listed species or destroy or adversely modify its critical habitat. 16 U.S.C. § 1536. To date, despite the fact that existing regulations require consultation on any action “directly or indirectly causing modifications to the land, water, or air,” 50 C.F.R. § 402.02, no federal agency has ever engaged in consultation regarding the impacts of greenhouse gas emissions flowing from a given agency action.

Analysis of the changing Arctic in federal decision-making:

Each of the statutes mentioned above require informed decision-making and the use of the best available science. Nevertheless, few if any agency decisions directly affecting the polar bear's Arctic habitat have properly taken into account the changing status of the species in a melting Arctic. For example, in August 2006, the Fish and Wildlife Service issued regulations under the MMPA allowing unlimited take of polar bears from all oil and gas related activities in the Beaufort Sea region for a period of five years. Despite a request from the Marine Mammal Commission to consider the impacts of global warming in making the required determination of "negligible impact" under the statute, the Service issued the authorization assuming impacts would be similar to those documented when similar authorizations were issued more than a decade previously and prior to the substantial changes of sea ice and polar bear population size and distribution evidenced by recent scientific observations. *See* 71 Fed. Reg. 43926 (Aug. 2, 2006).

As the above examples demonstrate, management decisions directly affecting the polar bear have not caught up with the science demonstrating significant changes in the status of the species and its Arctic ecosystem. As uninformed decision-making is often unwise decision-making, the polar bear will continue to be harmed by federal agency actions until and unless all relevant agencies start incorporating the most recent information regarding global warming and its impacts on the Arctic into their decision-making. Climate-informed decision-making is already the law; now it needs to be translated into action.

B. Reduce Other Stressors on Polar Bears and the Arctic

While a business-as-usual warming scenario would doom the polar bear to extinction and render any other conservation efforts irrelevant, saving the polar bear will require not just dramatically changing greenhouse gas emission trajectories but also addressing other cumulative threats to the species. While climate-informed decision-making will probably be better decision-making, and will reduce cumulative impacts to the polar bear, certain activities, no matter how thoroughly vetted, should simply no longer be allowed in polar bear habitat. Among these are activities that directly add black carbon to the Arctic (e.g., shipping) and activities that directly disturb polar bears and degrade their essential habitats (e.g., oil and gas development).

In 2003 the National Research Council noted that "[c]limate warming at predicted rates in the Beaufort Sea region is likely to have serious consequences for ringed seals and polar bears, and those effects will accumulate with the effects of oil and gas activities in the region." (NRC, 2003). Since the NRC report, both the impacts of global warming on the polar bear and the cumulative impacts of oil and gas activities have greatly accelerated. With the lease sales in the Beaufort and Chukchi seas scheduled under the 2007–2012 Program, and the ongoing rapid leasing and development of the NPR–A, the vast majority of polar bear habitat subject to U.S. jurisdiction, whether at sea or on land, is now open for oil and gas leasing and development. See Figure 8 (Map of existing and proposed leases in the Beaufort and Chukchi seas).

Polar bears in the Beaufort Sea and elsewhere are already undergoing food stress, and as a consequence resorting to cannibalism or simply starving (Amstrup et al., 2006; Regehr et al., 2006; Aars et al., 2006). Cub survival is down (Regehr et al., 2006; Aars et al., 2006). Denning has shifted from occurring mostly on ice to mostly on land and numerous bears now congregate on land pending the fall freeze-up of the sea-ice (Regehr et al., 2006; Aars et al., 2006). At the same time, the Beaufort Sea coast is becoming increasingly industrialized. This combination is potentially devastating for the species. Denning bears with reduced fat stores from a shorter hunting season are both more vulnerable to disturbance from oil industry activities and increasingly dependant upon areas subject to such industrial development. Similarly, hungry bears, trapped on land, are more likely to wander into oil camps and facilities looking for food, where their odds of being directly killed by humans acting in self-defense or being exposed to oil and other chemicals increases dramatically.

In addition to direct impacts on polar bears, oil industry activity also impacts their prey, such as ice seals which may be exposed to seismic surveys, icebreakers and other disturbances which could either harm these animals or render them less available for bears to hunt. Oil industry activity also results in methane and black carbon emissions in the Arctic from production activities, and of course substantial CO_2 emissions from the ultimate combustion of the recovered oil and gas.

Given the rapidly changing Arctic, the precarious status of polar bears, and the numerous adverse impacts of oil and gas industry activities on the species, we believe that there should be a moratorium on new oil and gas leasing and development in the range of the polar bear. Such a moratorium should be implemented immediately and remain in effect until and unless such activity can be demonstrated to not have adverse impacts on the polar bear, and any greenhouse emissions directly or indirectly associated with such activities are shown to be consistent with a comprehensive national plan to reduce CO_2 and non-CO_2 pollutants to levels determined necessary to avoid the continued loss of sea ice.

In addition to oil and gas activities, a growing cumulative threat to the polar bear is likely to be increased shipping in the Arctic which brings with it black carbon emissions, the risk of oil spills, and direct disruption and disturbance of polar bears and their prey. The U.S. should work in appropriate international fora such as the International Maritime Organization and the Arctic Council to prevent the establishment of new shipping routes in the Arctic. Simultaneously, the U.S. should require that any vessel transiting Arctic waters subject to U.S. jurisdiction utilize fuels and engine technologies that minimize black carbon emissions (*see, e.g.,* Ballo and Burt, 2007), and apply for and operate consistent with take authorizations under the MMPA and ESA so as to minimize direct impacts to polar bears and their prey.

Finally, persistent organic pollutants (POPs) represent a significant threat to polar bears and other Arctic species. As polar bears operate in an increasingly food-stressed state, they are likely to metabolize body fat containing unhealthy concentrations of POPs. The impact of POPs on individual polar bears can have both lethal and sub-lethal effects. As polar bear populations decline, and individual bears become more vulnerable, the disruptive cumulative effects of POPs on the species are likely to grow. Reduction or elimination of these compounds, both through application of U.S. law and international effort will likely provide substantial benefit to polar bears.

While many of the cumulative threats to the polar bear are subject to direct regulation by the U.S. and can and must be addressed immediately, the ultimate survival and recovery of the polar bear will require international efforts, not just to reduce greenhouse gas emissions and stabilize the climate system, but to protect the fragile Arctic habitat upon which the polar bear depends.

C. Towards an International Arctic Protection Regime

Ultimately, the protection of the polar bear and its Arctic habitat is the shared responsibility of not only the U.S., or even the five Arctic nations with polar bear populations, but of the broader global community. As global warming transforms and increases human access to the Arctic, we must be as proactive as possible in protecting this area. Since much of the Arctic is beyond any country's control, and many portions are now contested by competing national claims, a key component of an Arctic protection strategy rests in the international arena (See Figure 9). Just as the Antarctic Treaty arose in the context of competing national claims to that continent, the territorial disputes that are shaping up in the Arctic as the sea ice recedes and commercial exploitation of the region becomes foreseeable, present not just a threat, but an opportunity. Given we are entering the International Polar Year, the time is ripe to push for international action to permanently protect the shared treasure of the Arctic. The U.S. should proactively promote the large-scale protection of the Arctic through all existing international mechanisms, including the International Agreement for the Conservation of Polar Bears, the Arctic Council, and the United Nations Convention on the Law of the Sea. The U.S. cannot remain a spectator as other nations compete to divide up the resources of a newly accessible Arctic. We need to become participant, not to stake our own claims, but to lead efforts to render any such claims irrelevant, and shepherd the Arctic and the polar bear through the rapid changes of the coming decades.

IV. Conclusion

We are committed to saving the polar bear from the ravages of global warming for its own sake, as well as ours. Because the Arctic is the Earth's early warning system, what is happening to the polar bear now is a harbinger of what will happen to the rest of the world if business-as-usual politics and emissions continue. We cannot allow this to happen. It is not too late to save the Arctic-if we take action today. Immediate reductions in both CO_2 and non-CO_2 pollutants, along with protection of the Arctic from direct physical incursions, offer a true window of opportunity and hope. Acting to reduce greenhouse emissions in a timeframe rapid enough to save the polar bear will also provide us with the necessary urgency to tackle the challenge of global warming before its impacts drown not only polar bears but entire cities. We must begin immediately.

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Figure 1: Arctic Sea Ice Extent on September 21, 1979 (Source: NASA/Goddard Space Flight Center Scientific Visualization Studio)

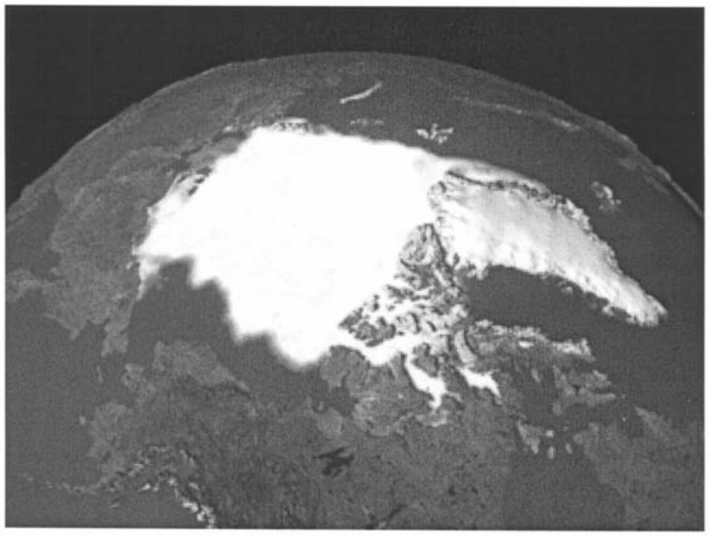


Figure 2: Arctic Sea Ice Extent on September 14, 2007 (Source: NASA/Goddard Space Flight Center Scientific Visualization Studio)

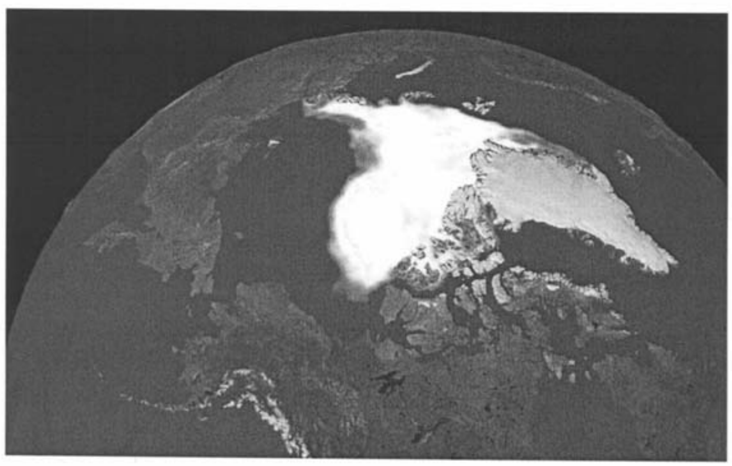


Figure 3: Polar Bear in the Final Stages of Starvation (Photo by Heiko Wittenborn)

Figure 4: Radiative Forcing Contribution of Greenhouse Gases (Data from Forster and Ramaswamy 2007:Table 2.1; chart does not include forcing from black carbon, which is a solid particle, not a gas).

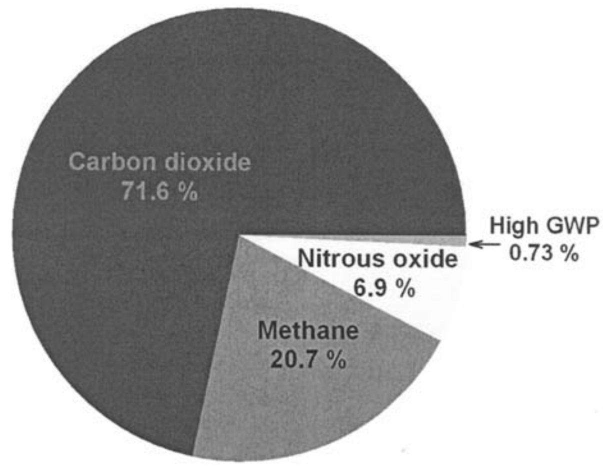


Figure 5: Non-CO_2 Emissions in the United States in 2010 by Sector (Data from EPA 2006)

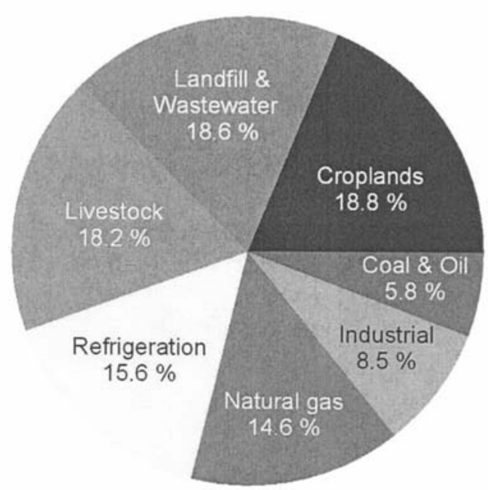


Figure 6: Methane Emissions and Potential Reductions for the United States in 2020 (Data from EPA 2006 and Table 2)

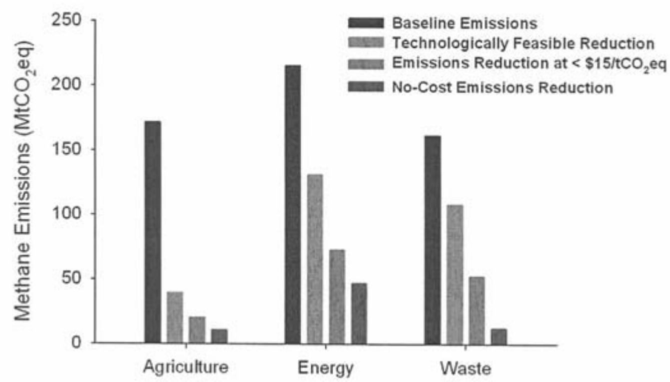


Figure 7: Global Methane Emissions and Potential Reductions in 2020 (Data from EPA 2006 and Table 4)

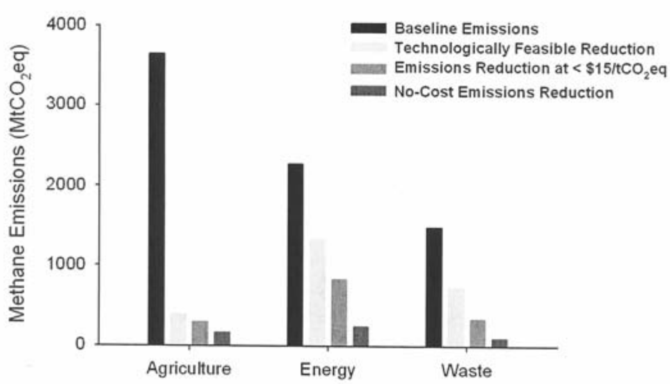


Figure 8: Current and Proposed Oil and Gas Leases on Alaska's North Slope

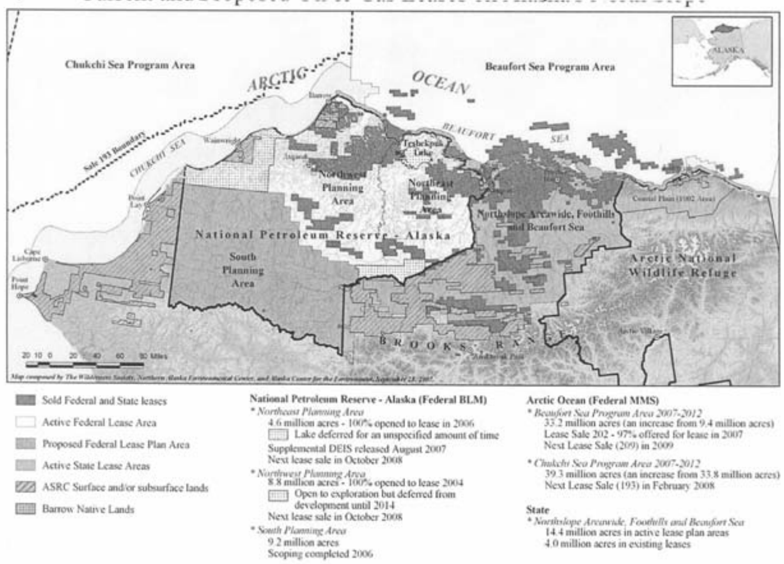
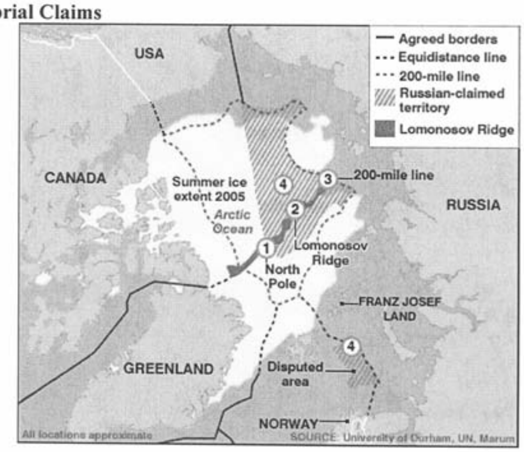


Figure 9: Arctic Territorial Claims



1) North Pole; 2) Lomonosov Ridge; 3) 200-nautical mile (370km) line; 4) Russian-claimed territory

Table 1: United States Non-CO_2 Emissions and Potential Reductions for 2010

Non-CO_2 Gas	*Sector*	*Baseline emissions ($MtCO_2eq$)*	***No-Cost reduction (%)***	*No-Cost reduction ($MtCO_2eq$)*	***< $15/ tCO_2eq reduction (%)***	*< $15/ tCO_2eq reduction ($MtCO_2eq$)*	***Techno-logically feasible reduction (%)***	*Techno-logically feasible reduction ($MtCO_2eq$)*
Methane (CH_4)	Livestock	173.0	**6.4**	11.1	**9.4**	16.3	**21.4**	37.0
	Landfill	125.4	**10.0**	12.5	**42.1**	52.8	**87.3**	109.5
	Wastewater	36.1	**N/A**					
	Coal mining	51.1	**49.2**	25.2	**86.0**	43.9	**86.0**	43.9
	Natural gas	138.6	**14.5**	20.1	**19.2**	26.7	**54.8**	75.9
	Oil	3.7	**0.0**	0.0	**17.7**	0.7	**21.8**	0.8
CH_4 Total		*527.9*	***13.0***	*68.9*	***26.6***	*140.4*	***50.6***	*267.1*
Nitrous Oxide (N_2O)	Wastewater	15.9	**N/A**					
	Croplands (wheat, maize, soy)	179.0	**21.7**	38.8	**25.9**	46.4	**28.5**	51.0
	Nitric acid	15.5	**0.0**	0.0	**88.9**	13.8	**88.9**	13.8
	Adipic acid	8.4	**0.0**	0.0	**96.0**	8.1	**96.0**	8.1
N_2O Total		*218.8*	***17.8***	*38.8*	***31.2***	*68.2*	***33.3***	*72.9*
HFCs	Refrigeration	148.6	**3.8**	5.7	**7.7**	11.4	**7.7**	11.4
	Solvents	1.7	**17.6**	0.3	**25.3**	0.4	**25.3**	0.4
	Foams	5.7	**3.3**	0.2	**3.7**	0.2	**6.8**	0.4
	Aerosols (medical)	2.7	**0.0**	0.0	**0.0**	0.0	**5.2**	0.1
	Aerosols (nonmed)	12.1	**38.6**	4.7	**38.6**	4.7	**38.6**	4.7
	Fire extinguishing	1.6	**0.0**	0.0	**0.0**	0.0	**6.9**	0.1
	HCFC-22 production	9.3	**0.0**	0.0	**86.7**	8.1	**86.7**	8.1
HFC Total		*181.7*	***6.0***	*10.8*	***13.7***	*24.8*	***13.9***	*25.2*
PFCs	Aluminum	4.6	**3.9**	0.2	**13.9**	0.6	**17.6**	0.8
	Semiconductor	5.5	**58.2**	3.2	**58.2**	3.2	**69.1**	3.8
PFC Total		*10.1*	***33.5***	*3.4*	***38.0***	*3.8*	***45.6***	*4.6*
SF_6	Electric power	12.8	**35.0**	4.5	**41.0**	5.3	**41.0**	5.3
	Mg production	1.2	**0.0**	0.0	**97.5**	1.2	**97.5**	1.2
SF_6 Total		*14.0*	***32.0***	*4.5*	***45.9***	*6.4*	***45.9***	*6.4*
All Gases		*952.5*	*13.3*	*126.4*	*25.6*	*243.6*	*39.5*	*376.3*

Emissions and potential reduction for global Non-CO_2 gases. All values are taken from EPA report 430-R-06-005, *Global Mitigation of Non-CO2 Greenhouse Gases* (2006). As discussed in the text, EPA (2006) calculations are conservative, and thus underestimate the no-cost and low cost mitigation opportunities. The baselines reported here do not account for all emissions; they only account for emissions that EPA determined should be considered for mitigation measures. Some sectors emit multiple types of greenhouse gas. In these instances, the emissions for the sector were attributed to the Non-CO_2 gas that is present in the largest proportion. For industries that have committed to some improvement in technology, the baseline and reductions are based on assumptions that these technologies will be adopted.

Table 2: United States Non-CO_2 Emissions and Potential Reductions for 2020

Non-CO_2 Gas	*Sector*	*Baseline emissions ($MtCO_2eq$)*	***No-Cost reduction (%)***	*No-Cost reduction ($MtCO_2eq$)*	***< \$15/ tCO_2eq reduction (%)***	*< \$15/ tCO_2eq reduction ($MtCO_2eq$)*	***Techno-logically feasible reduction (%)***	*Techno-logically feasible reduction ($MtCO_2eq$)*
Methane (CH_4)	Livestock	171.0	**6.3**	10.8	**11.8**	20.2	**23.0**	39.3
	Landfill	123.5	**10.0**	12.4	**42.1**	52.0	**87.3**	107.8
	Wastewater	37.8	**N/A**					
	Coal mining	46.4	**49.2**	22.8	**86.0**	39.9	**86.0**	39.9
	Natural gas	164.8	**14.5**	23.9	**19.2**	31.7	**54.8**	90.2
	Oil	4.5	**0.0**	0.0	**17.7**	0.8	**21.8**	1.0
CH_4 Total		*548.0*	*12.8*	*69.9*	*26.4*	*144.6*	*50.8*	*278.3*
Nitrous Oxide (N_2O)	Wastewater	16.3	**N/A**					
	Croplands (wheat, maize, soy)	200.0	**20.3**	40.6	**21.0**	42.0	**26.5**	53.0
	Nitric acid	17.4	**0.0**	0.0	**88.9**	15.5	**88.9**	15.5
	Adipic acid	9.8	**0.0**	0.0	**96.0**	9.4	**96.0**	9.4
N_2O Total		*243.5*	*16.7*	*40.6*	*27.5*	*66.9*	*32.0*	*77.9*
HFCs	Refrigeration	264.6	**11.4**	30.3	**29.5**	78.1	**29.5**	78.1
	Solvents	2.0	**37.0**	0.7	**52.5**	1.1	**52.5**	1.1
	Foams	11.3	**9.7**	1.1	**10.4**	1.2	**21.9**	2.5
	Aerosols (medical)	5.5	**0.0**	0.0	**0.0**	0.0	**49.8**	2.7
	Aerosols (nonmed)	14.8	**57.0**	8.4	**57.0**	8.4	**57.0**	8.4
	Fire extinguishing	1.9	**0.0**	0.0	**0.0**	0.0	**38.9**	0.7
	HCFC-22 production	8.5	**0.0**	0.0	**86.6**	7.4	**86.6**	7.4
HFC Total		*308.6*	*13.1*	*40.5*	*31.1*	*96.1*	*32.7*	*100.8*
PFCs	Aluminum	4.4	**4.1**	0.2	**14.8**	0.7	**18.4**	0.8
	Semiconductor	4.1	**29.3**	1.2	**29.3**	1.2	**31.7**	1.3
PFC Total		*8.5*	*16.2*	*1.4*	*21.8*	*1.9*	*24.8*	*2.1*
SF_6	Electric power	11.8	**0.0**	0.0	**31.3**	3.7	**31.3**	3.7
	Mg production	1.0	**0.0**	0.0	**90.0**	0.9	**90.0**	0.9
SF_6 Total		*12.8*	*0.0*	*0.0*	*35.9*	*4.6*	*35.9*	*4.6*
All Gases		*1121.4*	*13.6*	*152.4*	*28.0*	*314.0*	*41.3*	*463.7*

Emissions and potential reduction for global Non-CO_2 gases. All values are taken from EPA report 430-R-06-005, *Global Mitigation of Non-CO2 Greenhouse Gases* (2006). As discussed in the text, EPA (2006) calculations are conservative, and thus underestimate the no-cost and low cost mitigation opportunities. The baselines reported here do not account for all emissions; they only account for emissions that EPA determined should be considered for mitigation measures. Some sectors emit multiple types of greenhouse gas. In these instances, the emissions for the sector were attributed to the Non-CO_2 gas that is present in the largest proportion. For industries that have committed to some improvement in technology, the baseline and reductions are based on assumptions that these technologies will be adopted.

Table 3: World Non-CO_2 Emissions and Potential Reductions for 2010

Non-CO_2 Gas	*Sector*	*Baseline emissions ($MtCO_2eq$)*	***No-Cost reduction (%)***	*No-Cost reduction ($MtCO_2eq$)*	***< $15/ tCO_2eq reduction (%)***	*< $15/ tCO_2eq reduction ($MtCO_2eq$)*	***Techno-logically feasible reduction (%)***	*Techno-logically feasible reduction ($MtCO_2eq$)*
Methane (CH_4)	Rice	708	**10.5**	74.3	**21.9**	155.1	**24.9**	176.3
	Livestock	2548	**3**	76.4	**4.4**	112.1	**6.8**	173.3
	Landfill	760.6	**11.7**	89.0	**40.5**	308.0	**87.8**	667.9
	Wastewater	594	**N/A**					
	Coal mining	407.6	**16.6**	67.7	**79.8**	325.4	**79.8**	325.4
	Natural gas	1271.5	**10.1**	128.5	**25.0**	317.6	**53.4**	678.5
	Oil	82.9	**0**	0	**28.1**	23.3	**34.7**	28.8
CH_4 Total		*6372.6*	*6.8*	*436.0*	*19.5*	*1241.5*	*32.2*	*2050.1*
Nitrous oxide (N_2O)	Rice	330	**15.8**	52.14	**30.8**	101.64	**30**	99
	Wastewater	99.1	**N/A**					
	Croplands (wheat, maize, soy)	830	**15.4**	127.82	**17.6**	146.1	**24**	199.2
	Nitric acid	107	**0**	0	**88.9**	95.2	**88.9**	95.2
	Adipic acid	57.6	**0**	0	**96**	55.3	**96**	55.3
N_2O Total		*1423.7*	*12.6*	*180.0*	*28.0*	*398.2*	*31.5*	*448.7*
HFCs	Refrigeration	356.4	**4.7**	16.6	**8.2**	29.2	**8.9**	31.8
	Solvents	7.7	**10.4**	0.8	**23.8**	1.8	**23.8**	1.8
	Foams	15.4	**13.5**	2.1	**15.8**	2.4	**22.3**	3.4
	Aerosols (medical)	11	**0**	0	**0**	0	**5**	0.6
	Aerosols (nonmed)	32.7	**38.5**	12.6	**38.5**	12.6	**38.5**	12.6
	Fire extinguishing	7.4	**0**	0	**0**	0	**5.3**	0.4
	HCFC-22 production	44.7	**0**	0	**83.9**	37.5	**83.9**	37.5
HFC Total		*475.3*	*6.7*	*32.1*	*17.6*	*83.6*	*18.5*	*88.1*
PFCs	Aluminum	39.1	**2.9**	1.1	**13.6**	5.3	**15.7**	6.1
	Semiconductor	36.9	**39**	14.4	**40.1**	14.8	**51.5**	19
PFC Total		*76*	*20.4*	*15.5*	*26.5*	*20.1*	*33.1*	*25.1*
SF_6	Electric power	46.8	**45.8**	21.4	**50.2**	23.5	**50.2**	23.5
	Mg production	3.6	**0**	0	**94.4**	3.4	**94.4**	3.4
SF_6 Total		*50.4*	*42.5*	*21.44*	*53.4*	*26.9*	*53.4*	*26.9*
All Gases		*8398*	*8.2*	*685*	*21.1*	*1770.30*	*31.4*	*2638.9*

Emissions and potential reduction for global Non-CO_2 gases. All values with the exception of rice are taken from EPA report 430-R-06-005, *Global Mitigation of Non-CO2 Greenhouse Gases* (2006). As discussed in the text, EPA (2006) calculations are conservative, and thus underestimate the no-cost and low cost mitigation opportunities. The emissions for rice are from EPA report 430-R-06-003, *Global Anthropogenic Non-CO2 Greenhouse Gas Emissions 1990-2020* (2006). The baselines reported here do not account for all emissions; they only account for emissions that EPA determined should be considered for mitigation measures. Some sectors emit multiple types of greenhouse gas. In these instances, the emissions for the sector were attributed to the Non-CO_2 gas that is present in the largest proportion. For industries that have committed to some improvement in technology, the baseline and reductions are based on assumptions that these technologies will be adopted.

Table 4: World Non-CO_2 Emissions and Potential Reductions for 2020

Non-CO_2 Gas	*Sector*	*Baseline emissions ($MtCO_2eq$)*	***No-Cost reduction (%)***	*No-Cost reduction ($MtCO_2eq$)*	***< $15/ tCO_2eq reduction (%)***	*< $15/ tCO_2eq reduction ($MtCO_2eq$)*	***Techno-logically feasible reduction (%)***	*Techno-logically feasible reduction ($MtCO_2eq$)*
Methane (CH_4)	Rice	776.0	**10.5**	81.5	**21.9**	169.9	**24.9**	193.2
	Livestock	2867.0	**2.9**	83.1	**4.4**	126.1	**6.7**	192.1
	Landfill	816.9	**11.8**	96.6	**40.7**	332.3	**87.8**	716.9
	Wastewater	665.0	**N/A**					
	Coal mining	449.5	**14.5**	65.2	**79.8**	358.7	**79.8**	358.7
	Natural gas	1695.8	**10.2**	172.8	**25.3**	428.2	**53.8**	912.5
	Oil	131.8	**0.0**	0.0	**29.0**	38.2	**35.8**	47.2
CH_4 Total		*7402.0*	*6.7*	*499.2*	***19.6***	*1453.5*	***32.7***	*2420.6*
Nitrous Oxide (N_2O)	Rice	286.0	**13.1**	37.5	**26.3**	75.2	**27.0**	77.2
	Wastewater	107.2	**N/A**					
	Croplands (wheat, maize, soy)	893.0	**14.6**	130.4	**16.2**	144.7	**22.7**	202.7
	Nitric acid	113.1	**0.0**	0.0	**88.9**	100.6	**88.9**	100.6
	Adipic acid	63.5	**0.0**	0.0	**96.0**	61.0	**96.0**	61.0
N_2O Total		*1462.8*	*11.5*	*167.8*	***26.1***	*381.4*	***30.2***	*441.5*
HFCs	Refrigeration	627.3	**11.7**	73.2	**25.8**	161.7	**31.2**	195.8
	Solvents	4.5	**25.8**	1.2	**48.9**	2.2	**48.9**	2.2
	Foams	28.6	**16.2**	4.6	**19.4**	5.5	**30.8**	8.8
	Aerosols (medical)	20.1	**0.0**	0.0	**0.0**	0.0	**50.0**	10.1
	Aerosols (nonmed)	39.5	**57.1**	22.5	**57.1**	22.5	**57.1**	22.5
	Fire extinguishing	13.7	**0.0**	0.0	**0.0**	0.0	**27.5**	3.8
	HCFC-22 production	66.2	**0.0**	0.0	**87.9**	58.2	**87.9**	58.2
HFC Total		*799.9*	*12.7*	*101.5*	***31.3***	*250.2*	***37.7***	*301.4*
PFCs	Aluminum	44.7	**3.0**	1.3	**14.0**	6.2	**16.2**	7.2
	Semiconductor	28.3	**44.2**	12.5	**44.2**	12.5	**51.2**	14.5
PFC Total		*73.0*	*19.0*	*13.8*	***25.7***	*18.7*	***29.8***	*21.7*
SF_6	Electric power	57.5	**40.9**	23.5	**50.2**	28.9	**50.2**	28.9
	Mg production	4.8	**0.0**	0.0	**96.5**	4.6	**96.5**	4.6
SF_6 Total		*62.3*	*37.7*	*23.5*	***53.8***	*33.5*	***53.8***	*33.5*
All Gases		*9800.0*	*8.2*	*805.9*	*21.8*	*2137.4*	*32.8*	*3218.7*

Emissions and potential reduction for global Non-CO_2 gases. All values with the exception of rice are taken from EPA report 430-R-06-005, *Global Mitigation of Non-CO2 Greenhouse Gases* (2006). As discussed in the text, EPA (2006) calculations are conservative, and thus underestimate the no-cost and low cost mitigation opportunities. The emissions for rice are from EPA report 430-R-06-003, *Global Anthropogenic Non-CO2 Greenhouse Gas Emissions 1990-2020* (2006). The baselines reported here do not account for all emissions; they only account for emissions that EPA determined should be considered for mitigation measures. Some sectors emit multiple types of greenhouse gas. In these instances, the emissions for the sector were attributed to the Non-CO_2 gas that is present in the largest proportion. For industries that have committed to some improvement in technology, the baseline and reductions are based on assumptions that these technologies will be adopted.

Table 5: Global Mean Annual Budget of BC for Different Geographical Regions

Region	Emissions Tg/yr (regional contribution)	Contribution of Biofuels (regional contribution)	Global Dry Deposition (Tg/yr)	Global Wet Deposition (Tg/yr)	Burden x 100 Tg (regional contribution)	Residence Time (days)	Contribution to Surface Deposition North to 60N, South to 60S
SAM	0.314 (6%)	5%c (25%)	0.049	0.265	0.452 (6.5)%	5.28	1%
NAM	0.522 (11%)	6% (20%)	0.092	0.430	0.697 (10.0%)	4.80	11%
AFR	0.483 (10%)	21% (72%)	0.088	0.395	0.947 (13.6%)	7.16	1%
EUR	0.602 (12%)	5% (13%)	0.128	0.474	0.823 (11.8%)	5.01	63%
WCA	0.157 (3%)	1% (11%)	0.040	0.117	0.312 (4.5%)	7.29	2%
SAS	0.602 (13%)	25% (68%)	0.120	0.483	1.086 (15.6%)	6.59	2%
EAS	2.038 (43%)	36% (29%)	0.333	1.708	2.565 (36.8%)	4.60	17%
AUP	0.036 (1%)	<1% (14%)	0.006	0.030	4.062 (0.7%)	4.62	1%
OCE	0.036 (1%)	– (–)	0.007	0.029	0.042 (0.6%)	4.24	2%
Global	**4.791**	**34%**	**0.860**	**3.931**	**6.970**	**5.32**	–

Table 1 from Reddy, M.S. and Boucher, O (2007), Climate impact of black carbon emitted from energy consumption in the world's regions, *Geophysical Research Letters*, 34: L11802. Regional abbreviations: SAM, South America; NAM, North America; AFR, Africa; EUR, Europe; WCA, West and Central Asia; SAS, South Asia; EAS, East Asia; AUP, Australia and Pacific Islands; OCE, Oceanic Regions.

APPENDIX A:

Mitigation Strategies for Non-CO_2 Pollutants

The primary non-CO_2 pollutants are methane, black carbon (soot), nitrous oxide, and the high global warming potential gases (Figure 4). The global warming potential of each of these pollutants is more powerful than carbon dioxide—21 (methane) to 23,000 (sulfur hexafluoride) times as powerful over a 100 year period (Forster and Ramaswamy, 2007). The duration over which each of the gases is present in the atmosphere and contributing to the greenhouse effect varies from 12 years (methane) to centuries (fluorinated gases). For ease of comparison, the volume of each pollutant is expressed throughout this report as its "carbon dioxide equivalent" in millions of metric tons. Thus, one million metric tons of methane is equivalent to 21 million metric tons of CO_2 equivalent ($MtCO_2eq$).

A. Methane

Methane is the most important of the non-CO_2 pollutants, with a global warming potential 21 times greater than carbon dioxide, and an atmospheric lifetime of 12 years (Forster and Ramaswamy, 2007). Methane constitutes approximately 20 percent of the anthropogenic greenhouse gas effect globally, the largest contribution of the non-CO_2 gases. However, methane emissions anywhere in the world will have a disproportionate warming impact in the Arctic, due to the fact that methane is also an ozone precursor. Tropospheric ozone, unlike other greenhouse gases, absorbs both infrared radiation and shortwave radiation (visible light). Thus, tropospheric ozone is a particularly powerful greenhouse gas over highly reflective surfaces like the Arctic, because it traps shortwave radiation both as it enters the Earth's atmosphere from the sun and when it is reflected back out again by snow and ice. Reducing global methane emissions will reduce ozone concentrations in the Arctic, providing a double benefit to the region.

According to conservative projections by the U.S. EPA, about 500 $MtCO_2eq$ of global methane emissions reductions could be achieved globally by 2020 at a cost benefit or no cost (EPA, 2006; Table 4, Figure 7). Nearly 70 $MtCO_2eq$ of these available reductions are in the United States (EPA, 2006; Table 2, Figure 6). The EPA estimates total technically feasible methane reductions for 2020 at over 2400 $MtCO_2eq$ globally and nearly 280 $MtCO_2eq$ in the U.S., many of which can be achieved at low cost (EPA, 2006; Tables 2 and 4; Figures 6,7).

The EPA's cost projections are conservative for a number of reasons, including the use of a 10 percent discount rate. Using a lower discount rate would result in additional cost benefit or no-cost reductions. Moreover, the EPA analysis does not account for the value of significant air quality and health benefits that would accompany methane reductions. West et al. (2006) found that reducing global methane emissions by 20 percent would save 370,000 lives between 2010 and 2030, due to the reduction in ozone related cardiovascular, respiratory, and other health impacts. Methane reductions would also decrease ozone-related damage to ecosystems and agricultural crops (West et al., 2006). Methane is the primary component of natural gas, and many abatement options include the use of captured methane to generate energy. The benefits of displacing other fossil fuel energy sources with captured methane are also not captured in the EPA (2006) analysis.

While EPA (2006) may underestimate available no-cost and low cost methane (and other non-CO_2 gas) mitigation options, even this conservative analysis shows the enormous opportunities available to us today (Tables 1–4; Figures 6–7). These reductions can be achieved with technology available today. Moreover, mandatory greenhouse gas regulation will speed the development and deployment of new technology and mitigation options, making much deeper reductions feasible in the very near future.

1. The Waste Sector

Methane produced in the waste sector comes from two main sources: landfills and wastewater. Landfills produced approximately 12 percent of all global methane emissions in 2000. Landfills provide one of the largest single sources of available emissions reductions, as the EPA (2006) estimates that 88 percent of landfill methane emissions could be abated with existing technology. Methane is produced in managed (sanitary) landfills due to the anaerobic decomposition of organic waste. Approximately 50 percent of landfill gas is methane and the other 50 percent is largely made up of carbon dioxide. Sanitary landfills are found predominately in developed countries. Open dumps that do not promote anaerobic conditions are more common in developing nations, but these countries are rapidly adopting landfill management techniques because of the many advantages of sanitary waste disposal.

In the U.S., large landfills with capacity exceeding 2.5 megagrams (2.8 million short tons) are regulated under the *Clean Air Act.*[1] Despite the current programs in place, the U.S. is the largest source of landfill methane in the world, producing in 2000 nearly three times as much landfill emissions as the next largest producer, China (EPA, 2006: III–5).

Landfill methane can be abated either through capture and flaring or use for energy generation, or by diverting organic material from landfills and into composting and recycling-reuse programs. Landfill gases are already captured and flared at a number of U.S. landfills. A preferable option is to use the methane directly for electricity or heat generation, or to sell it to industrial users for energy use (EPA, 2006). Using methane for energy generation, as opposed to simply flaring it, has the additional benefit of displacing the emissions that would have resulted from otherwise supplying the energy created.

The second source of waste emissions is wastewater. Wastewater contributes approximately nine percent of global methane emissions (EPA, 2006). Domestic wastewater processing involves removing organic matter, solids, pathogens, and chemicals. These produce a biomass "sludge" that is digested either anaerobically to produce methane, or aerobically to produce carbon dioxide. Approximately 45 percent of the sludge is usually digested, and the remainder is sent to landfills. The amount of methane produced is proportional to the organic content of the sludge.

Industrial sources with especially high organic content include meat and poultry processing, pulp and paper processing, and produce processing industries. The EPA estimates that 77 percent of meat and poultry wastewater degrades anaerobically due to use of lagoons. Similarly, lagoons are used for pulp and paper processing.

The abatement options for wastewater include: (1) reduced anaerobic digestion and (2) collection and subsequent flaring or utilization. Reductions in anaerobic digestion can be accomplished through aeration and reduced usage of settling lagoons. Collection is used in series with an anaerobic digester. The collected methane can be flared, or preferably used for energy generation. EPA (2006) states that because most centralized wastewater treatment facilities already either flare or use captured methane for safety reasons, the "add-on" abatement options to existing systems are limited. Large abatement opportunities depend primarily on the creation of managed wastewater treatment systems in developing countries, which will require large-scale structural changes in wastewater management practices (EPA, 2006). Because the primary motivation for the installation of improved wastewater treatment has historically been the direct public health benefits from disease prevention, EPA (2006) did not calculate cost estimates. The increasing use of centralized wastewater treatment facilities worldwide is clearly necessary and will bring enormous benefits both for public health and climate change mitigation.

2. The Energy Sector

Enormous methane mitigation potential exists in the energy sector. The three main sources globally are natural gas systems (16 percent of total methane emissions), coal mining (six percent) and oil (0.95 percent). Abatement opportunities from natural gas systems are particularly promising as natural gas is a rational transition fuel as the global economy is decarbonized. Oil is more carbon-intensive than natural gas, and coal the most carbon-intensive of all. Coal-fired power plants, and therefore coal mining, must be reduced and then eliminated. Nevertheless, methane abatement opportunities currently exist and should be implemented wherever mining continues. Mitigation opportunities are also available for abandoned coal mines.

[1] In March of 1996, EPA promulgated guidelines (61 Fed. Reg. 9905) for controlling the emissions from existing Municipal Solid Waste landfills and the New Source Performance Standards for new or modified Municipal Solid Waste landfills under authority of Section 111 of the *Clean Air Act.* Although there are some differences in requirements for landfills constructed or expanded under different stages of the development of the regulations, in general the guidelines required the following:

1) Installation of gas collection and control systems for new and modified landfills designed to hold 2.755 million tons or more of waste over their lifetime, and that could be expected to emit more than 50 megagrams per year of non-methane organic compounds (NMOC).

2) When any landfill reaches the above thresholds, it must within 30 months install a gas collection and control system that covers all portions of the landfill. The collected landfill gas must be combusted at a high enough temperature to destroy 98 percent of the toxics.

3) Three conditions be met prior to capping or removal of the collection and control system: (1) The landfill must be permanently closed; (2) the collection and control system must have been in continuous operation a minimum of 15 years; and (3) the annual NMOC emission rate routed to the control device must be less than 50 megagrams per year.

The United States is the top consumer of natural gas and is second only to the Russian Federation in methane emissions from natural gas systems. Methane emissions occur during production, processing, transmission and storage, and distribution of natural gas. There are a variety of mitigation options that address each of these stages.

During extraction, the gas is passed through dehydrators to remove water and other liquids. It is then transported through lines to a processing facility for further refinement. The processed gas, which is 95 percent methane, is then compressed and transmitted to storage and distribution facilities. Finally, the gas is decompressed to be distributed for home or commercial use.

Leakage from lines and equipment is the main source of methane emissions. These emissions can be abated through a variety of methods, which can be broadly categorized as changes in operational practice, equipment upgrade and replacement, and though direct inspection and maintenance. A number of these measures will actually save the operator money, on the order of 20–25\$/tCO_2eq (EPA, 2006:II–27).

The second largest source of energy sector methane emissions is coal mining. Methane is produced as organic matter turns to coal. It accumulates in pockets near a coal seam, and is eventually released during the mining process. More methane is produced by deeper seams. Because methane is dangerous, it is extracted and usually vented to the atmosphere. Some methane is also produced during coal processing and from abandoned mines.

Abatement of mining-related emissions may be through one of three broad methods: (1) degasification, where methane is captured but not vented prior to operations; (2) enhanced degasification, which involves special drilling techniques and capture and use of methane; and (3) oxidation of ventilation air methane (VAM) to produce energy (EPA, 2006). Approximately 57 percent of the methane obtained through degasification—the drilling of wells or boreholes prior to mining—can be piped out and sold for energy. If additional enrichment techniques are used to further refine the methane obtained during degasification, called enhanced degasification, approximately 77 percent of the methane may be sold for energy. Finally, approximately 97 percent of ventilation air methane, which is a much lower concentration, can be mitigated through oxidation and use for local energy. Due to its low concentration of methane, this gas is not suitable for distribution.

Because the captured methane can be used or sold for energy, approximately 17 percent of emissions can be abated at no cost or positive economic benefit. At a cost of less than 15\$ per tCO_2eq, approximately 80 percent of emissions from coal mining could be eliminated. Profitable options have been addressed in EPA's Coalbed Methane Outreach Program started in 2001 to reduce and use coal mine methane (*http://www.epa.gov/cmop/resources/webbrochure.html*).

The third major energy-sector source of methane is oil production. Fugitive emissions are released during crude oil production, transportation, and refining (EPA, 2006). Oil production accounts for approximately 97 percent of these methane emissions. Methane emissions from onshore oil production are more easily captured and transported than those from offshore production.

The major sources of production emissions are: volatilization of high pressure crude oil as it enters the holding tank, equipment leaks and vessel blowdowns (removal of liquids through pressurization), and fugitive leaks and combustion during flares (EPA, 2006).

There are three abatement options: (1) flaring instead of venting; (2) direct use for energy; and (3) reinjection of the methane to the oilfield to enhance later oil recovery. Safety considerations make flaring more feasible at onshore facilities. This measure has the potential to reduce methane emissions by 98 percent over 15 years. Flaring is the least preferred mitigation option as it does not produce energy, thereby displacing other emissions, yet results in additional CO_2 emissions. The second option is the direct use of the methane for energy at offshore platforms, and has the potential to reduce 90 percent of methane emissions. The third option is to reinject the methane into the oilfield. This can reduce methane emissions by 95 percent over 15 years.

3. The Agricultural Sector

Agriculture accounts for approximately 52 percent of global methane emissions, and these are expected to increase by 30 percent in 2020 (over 2000 levels). The main agricultural sources of methane are rice fields and livestock. Methane emissions from rice fields occur due to anaerobic decomposition of organic matter in flooded rice fields. The majority (90 percent of emissions) of rice production occurs in Asia. Management practices that include variation in the timing of field flooding, tilling practices, and fertilization can reduce the amount of methane production.[2]

The second major source of agricultural methane is livestock. This includes both methane gas emitted by ruminants as a result of digestion (enteric fermentation) and methane emitted by manure. While all ruminants produce some methane, the majority of global methane emitted due to enteric fermentation comes from cows used for beef and dairy production. Switching to higher quality feed and lower volumes of feed can reduce methane from enteric fermentation because high quality feed increases the proportion of energy that is available for use by the animal and consequently reduces the amount that is wasted as methane.[3] As a result, these mitigation options actually have a net economic benefit for the producer.

Methane is also produced by manure during anaerobic decomposition. These conditions occur when liquid manure is stored in lagoons, ponds, tanks, and pits. The trend in the U.S. is to increasingly store manure under these conditions. Furthermore, duration of time stored in this manner and temperature affect the amount of methane that is produced.

The mitigation options for manure methane involve different types of methane digesters that can capture the methane and produce energy. A manure digester is a system of containers to collect and biologically treat manure with naturally occurring microorganisms. The anaerobic environment facilitates the generation and capture of methane. The methane can then be burned to convert to CO_2, and to produce heat and/or electricity. Digesters may also include systems to collect and separate solids. Large-scale digesters can be used for capture and off-site energy use while temperature digesters can be used at smaller facilities where the energy is used onsite.

C. Black Carbon or Soot

Black carbon, or soot, consists of particles or aerosols released through the burning of fossil fuels, biofuels, and biomass (Quinn et al., 2007). Black carbon warms the atmosphere, but it is a solid, not a gas. Unlike most greenhouse gases that warm the atmosphere by absorbing longwave infra-red radiation, soot warms the atmosphere by absorbing visible light (Chameides and Bergin, 2002). Black carbon is an extremely powerful greenhouse pollutant. Scientists have described the average global warming potential of black carbon as about 500 times that of carbon dioxide over a 100 year period (Hansen et al., 2007; see also Reddy and Boucher, 2007; Bond and Sun, 2005). This powerful warming impact is remarkable given that black carbon remains in the atmosphere for only about four to seven days, with a mean residence time of 5.3 days (Reddy and Boucher, 2007).

Black carbon contributes to Arctic warming through the formation of "Arctic haze" and through deposition on snow and ice, which increases heat absorption (Quinn et al., 2007; Reddy and Boucher, 2007). Arctic haze results from a number of aerosols in addition to black carbon, including sulfate and nitrate (Quinn et al., 2007). Arctic haze may either increase or decrease warming, but when the haze contains high amounts of soot, it absorbs incoming solar radiation and leads to heating. In addition, aerosols may interact with clouds changing droplet number and size, which in turn can alter albedo, or reflectivity.

Soot also contributes to heating when it is deposited on snow because it reduces reflectivity of the white snow and instead tends to absorb radiation. A recent study indicates that the direct warming effect of black carbon on snow can be three times as strong as that due to carbon dioxide during springtime in the Arctic (Flanner, 2007). Black carbon emissions that occur in or near the Arctic contribute the most to the melting of the far north (Reddy and Boucher, 2007; Quinn et al., 2007).

Reductions in black carbon therefore provide an extremely important opportunity to slow Arctic warming in the short-term, and mitigation strategies should focus on within-Arctic sources and northern hemisphere sources that are transported by air currents most efficiently to the Arctic. Conversely, allowing black carbon emissions to increase in the Arctic as the result of increased shipping or industrial activity, will accelerate loss of the seasonal sea ice and extinction of the polar bear. Black carbon reductions will also provide air quality and human health benefits.

Despite its significance to global climate change and to the Arctic in particular, black carbon has not been addressed by the major reports on non-CO_2 gas mitiga-

[2] Some agricultural practices which reduce methane emissions lead to an increase in nitrous oxide production, and thus mitigation options must be carefully tailored so that only measures resulting in a net decrease in greenhouse gas emissions are implemented.

[3] High-energy feed, such as grain, can also increase the methane produced by the manure. However, the need for a trade-off between lower enteric fermentation emissions and manure emissions will be eliminated if manure emissions are mitigated through the use of digesters.

tion, nor is it explicitly addressed in current global warming bills in the 110th Congress. Black carbon reductions are an essential part of saving the Arctic sea ice and the polar bear, and should be addressed by Congress in this session.

The highest priority sources for regulation include the following: diesel generators and residential stoves within the Arctic, ships operating in or near Arctic waters, diesel truck and automobile engines, and biomass burning.

Specific measures that should be implemented include replacing diesel generators with alternative energy sources, improving the efficiency and/or particulate matter traps on residential stoves, or fuel switching in residential stoves.

Ships operating in or near Arctic waters can introduce black carbon directly into the region and should therefore be stringently regulated. One of the simplest ways to reduce black carbon emissions from ships is simply to slow them down (Ballo and Burt, 2007:26). A ten percent reduction in speed can result in a 23.3 percent reduction in emissions (Ballo and Burt, 2007:27). Requiring ships to switch to cleaner, lower sulphur content fuels will also reduce black carbon emissions (Ballo and Burt, 2007:29). There are a variety of design changes available to increase the efficiency of ships and therefore decrease their emissions (Kleiner, 2007). Finally, shipping should be stringently limited in the Arctic, as discussed above.

All diesel engines are a significant contributor to black carbon emissions. Emissions from diesel cars and trucks should be more stringently regulated (Jacobson, 2002). Abatement options include upgrading vehicles, installing end of the pipe filters, better vehicle maintenance, and buy out/buy back programs for super emitters.

Emissions reductions from biomass burning and other sources are most important when the Arctic ice extent is relatively large (Quinn et al., 2007), and therefore regulating both the amount and timing of anthropogenic biomass burning can also reduce black carbon levels in the Arctic.

Much more attention needs to be focused on identifying and implementing black carbon emissions from all sources.

D. Nitrous Oxide

Unlike methane and black carbon, nitrous oxide and the high global warming potential gases discussed below do not have a disproportionate impact on the Arctic. Nevertheless, because these gases have high global warming potential, long atmospheric lifetimes, and because there are many readily available mitigation measures to reduce them, they present important opportunities for reducing global warming overall and are therefore an important part of saving the Arctic and the polar bear.

Nitrous oxide has a global warming potential 310 times that of carbon dioxide and an atmospheric lifetime of approximately 120 years. It constitutes the second largest proportion of anthropogenic non-CO_2 gases at seven percent. The main sources of nitrous oxide emissions are: agriculture, fossil fuel combustion, and industrial adipic and nitric acid production.

1. Agriculture

Agriculture is the largest source of anthropogenic nitrous oxide (84 percent) (EPA 2006). These emissions are projected to increase by 37 percent in 2020 (over 2000 levels). Agricultural nitrous oxide is produced primarily (1) through the processes of nitrification and denitrification of soil, (2) by livestock manure, and (3) from rice farming.

Nitrous oxide emissions occur as a result of addition of nitrogen to the soil through fertilization, nitrogen-fixing crops, retention of crop residues, and cultivation of high organic content soil (peat or histosol) (EPA, 2006). Nitrous oxide emissions can also result from volatilization of applied nitrogen and runoff.

In 2000, the United States' soil nitrous oxide emissions were second only to the former Soviet Union, and are predicted to surpass the FSU by 2010. Practices such as irrigation, drainage, tillage, and fallowing all influence nitrous oxide emissions.

An important consideration when selecting abatement options is that a number of practices may reduce nitrous oxide emissions while increasing carbon dioxide emissions, resulting in a net increase in greenhouse gases. The abatement options presented below are those that do not result in increased carbon dioxide emissions.

The options include reduced fertilization or more efficient fertilization, and no-till management to maintain at least 30 percent of the ground covered by crop residue after planting. The most effective fertilization option is the use of a fertilizer that includes a nitrification inhibitor. No-till, or conservation tillage, is effective primarily because it reduces carbon loss. The net reductions potential for croplands is approximately 24 percent, with 15 percent possible at zero net cost.

Rice fields produce both methane and nitrous oxide. The cycle, however, is different for each of the gases so that some methods that reduce one gas may increase the other. Thus, management practices must be considered carefully to balance the effects. Shallow flooding, off-season straw, and ammonium sulfate are the management practices that can reduce nitrous oxide emissions as well as methane emissions. The practice of mid-season drainage reduces methane substantially while increasing nitrous oxide. Yet, due to the magnitude of methane reduction, this practice results in a net reduction of equivalent greenhouse gases.

The final major agricultural source of nitrous oxide is livestock manure. The practices outlined above for reductions in methane emissions from livestock manure also apply to reductions in nitrous oxide.

2. Industrial production

The production of nitric and adipic acid account for approximately five percent of nitrous oxide emissions. Nitric acid accounts for approximately 67 percent and adipic acid accounts for approximately 33 percent of emissions. Nitric acid is used in fertilizers as well as explosives, metal processing, and etching. Adipic acid is a component of nylon, synthetic lubricants and plastics, polyurethane resins, and plasticizers. It is also used in some artificial foods to impart a "tangy" flavor.

Plants that produce nitric acid and do not employ nonselective catalytic reduction may generate up to 19 kilograms of nitrous oxide per ton of nitric acid. The majority of plants in the U.S. do not use this technology, and approximately 80 percent of plants worldwide do not use it. Nitric acid plants can reduce their emissions by 90 to 95 percent through high-temperature or low-temperature catalytic reduction. The costs are minor: approximately \$2–\$6/tCO_2eq. The high-temperature option is less expensive and reduces nitrous oxide by 90 percent. The low-temperature option costs slightly more and reduces emissions by 95 percent.

The abatement option for adipic acid plants is thermal destruction. This option costs only \$0.50/tCO_2eq and can reduce nitrous oxide emissions by 98 to 99 percent.

E. High Global Warming Potential Gases

High global warming potential (High-GWP) gases fall into three broad categories: hydrofluorocarbons (HFCs), perfluorcarbons (PFCs), and sulfur hexafluoride. Hydrofluorocarbons were developed to replace ozone-depleting substances used in refrigeration and air conditioning systems, solvents, aerosols, foam production, and fire extinguishing. HFCs have global warming potentials between 140 and 11,700 times that of carbon dioxide, and their atmospheric lifetimes range from one year to 260 years, respectively.

Perfluorocarbons are emitted during aluminum production and semiconductor manufacture (EPA, 2006). Their global warming potential ranges from 6,500 to 9,200 times that of carbon dioxide. In addition, they have extremely long atmospheric lifetimes, e.g., 10,000 and 50,000 years for two common PFCs.

The highest global warming potential exists in sulfur hexafluoride at 23,900 times that of carbon dioxide. Sulfur hexafluoride remains in the atmosphere for 3,200 years. Sulfur hexafluoride is used: (1) for insulation and current interruption in electrical power transmission and distribution; (2) during semiconductor manufacture; (3) to protect against burning in the magnesium industry.

1. Hydrofluorcarbons

a. Refrigeration and Air Conditioning

Hydrofluorocarbons are used for refrigeration and air conditioning, solvents, foam manufacture, aerosols, and in fire extinguishers. The emission of hydrofluorocarbons related to refrigeration occurs during manufacturing and servicing, leaks during operation, and disposal. An indirect effect of using these systems is the use of energy and resulting emission of carbon dioxide. Thus, mitigation measures should be evaluated both for direct HFC emissions as well as carbon dioxide emissions.

There are a variety of uses for refrigeration systems: household refrigeration, car air-conditioning, chillers for large spaces such as shopping malls as well as submarines and nuclear reactors, retail food refrigeration, cold storage warehouses, refrigerated transport, industrial refrigeration during manufacture, and residential and commercial air conditioning and heat pumps. Because a number of these systems currently use ozone-depleting substances that are being phased out as equipment ages, the impact of switching systems has been incorporated into the mitigation analysis (EPA, 2006).

The abatement options fall into three categories: practice options, alternative refrigerant options, and technology options. Practice includes actions such as leak repair, refrigerant recovery/recycling, and sales restrictions on HFCs. The alternative refrigerants include ammonia, hydrocarbons such as isobutene, and carbon dioxide.

Many of the abatement options carry a net economic benefit, such that the U.S. alone could reduce over 20 metric tons CO_2eq emissions by the year 2020 at no cost or at a net economic benefit.

b. Solvents

Solvents used in precision and electronic cleaning, and to a much lesser extent metal cleaning, have replaced ozone-depleting substances in a variety of ways, including substitution of HFCs and PFCs. There are three main mitigation options: (1) improved solvent containment and use of carbon absorption; (2) use of aqueous or semi-aqueous cleaning processes; and (3) conversion to different low-global warming potential compounds or organic compounds.

The conversion to alternative compounds is a no-cost abatement option that could reduce baseline emissions by approximately 25 percent by the year 2020. Similarly, conversion to semi-aqueous cleaning processes would only cost approximately \$0.67/ tCO_2eq.

c. Foam manufacture

HFCs are used during the blowing process to produce foam. These emissions are expected to rise dramatically in coming years. Another ozone-depleting substance, hydrochloroflurocarbons (HCFCs), is still in use in developing countries, but will be phased out with time. The U.S. currently allows the use of HCFC–22, but not HCFC–141b.

Emissions occur during the manufacture process, during foam application, while foams are in use, and when they are discarded. Abatement can be achieved through replacement of the blowing agent used in the manufacture process and proper disposal of appliance foam at end-of-life. Several of the replacement options would bring a net economic benefit. The total possible reduction from the predicted 2020 baseline emissions is approximately 31 percent.

d. Aerosols

Aerosols are used to propel a variety of products. After CFCs were banned in the U.S., some products began using HFCs as propellants. Medical applications, such as inhalers, currently still use CFCs, but these companies are developing HFC alternatives.

Abatement of non-medical HFC emissions involves replacing current HFCs with other HFCs that have a lower global warming potential, hydrocarbon propellants, and other application methods such as hand pumps, roll-on applicators, and powders. All of these non-medical options can be achieved at no cost and would reduce current HFC emissions by at least 57 percent in the year 2020.

Transitioning away from CFCs has proven to be a challenge with medical inhalers. One alternative for some patients, however, is the use of dry powdered inhalers. The use of this application method has the capability of reducing medical propellant HFC emissions by half.

e. Fire Extinguishing

Halon was traditionally used in fire extinguishing systems—both portable fire extinguishers and “total flooding” systems that protect large spaces. Due to its ozone depleting characteristics, halon is being replaced in some instances with HFCs.

Depending on the application, HFC systems can be replaced by inert gas systems, water mist systems, or fluorinated ketone systems. In addition, abatement can be achieved through recovery and reuse of HFCs and through improved detection mechanisms to prevent erroneous release in total flooding systems.

f. HCFC–22

As mentioned above, HCFC–22 is an ozone depleting substances that is used in refrigeration, some solvents, and synthetic polymer production. One of the byproducts is HFC–23, which has a global warming potential of 11,700 times that of carbon and an atmospheric lifetime of 260 years. The U.S. is close behind China as the second largest producer of HFC–23 emissions resulting from production of HCFC–22.

There are several options for mitigating HFC emissions. Manufacturing optimization can maximize HCFC–22 production and minimize HFC–23 production at very lost cost. Thermal oxidation of HFC–23 by product can reduce 95 percent of HFC emissions. Oxidation costs only about \$0.23/tCO_2eq and can reduce HFC emissions at existing plants by 88 percent, even assuming that current plans to minimize HCFC–22 are implemented.

At the commemoration meeting of the Montreal Protocol on September 21, 2007, the U.S. and other developed nations agreed to a schedule of reductions that includes ceasing to use HCFCs by 2020, which is 10 years sooner than previously agreed. Thus, the assumptions upon which the EPA 2006 report were based may be inapplicable.

2. Perfluorocarbons

a. Aluminum production

The aluminum industry is the largest source of PFC emissions. PFCs are emitted when so-called anode effects occur during the smelting process. The amount of PFCs emitted depends directly on the number and duration of such events.

Although the aluminum industry has taken voluntary reductions and has pledged further reductions, there are still mitigation options that should be implemented to further reduce emissions. The two main methods are: installation of computer control systems and installation of alumina point-feed systems. The computer control system is considered a minor retrofit and the alumina point-feed system is considered a major retrofit. The efficacy of these measures depends on the current technology used by the plant. They may reduce PFC emissions by up to 97 percent when combined at some facilities. The implementation of these options can also come at an economic benefit in some facilities.

b. Semiconductor manufacturing

The manufacture of semiconductors releases PFCs, sulfur hexafluoride, and HFC–23 primarily during plasma etching of thin films and cleaning chemical-vapor-deposition (CVD) chambers. Etching is estimated to account for approximately 20 percent of emissions, while CVD chamber cleaning accounts for approximately 80 percent. PFC emissions also occur as a by-product of reactions between other gases. The U.S. is the second largest emitter of PFCs, although it is a member of the World Semiconductor Council, which has committed to voluntary reductions in emissions.

The most effective abatement option is nitrogen trifluoride remote cleaning technology. This system can reduce emissions by approximately 95 percent. This option has a net economic benefit and when implemented could reduce baseline emissions by 42 percent, even assuming the industry meets its voluntary emissions reduction goal. The second most effective option is point-of-use plasma abatement during the etching process.

3. Sulfur hexafluoride

a. Electrical industry

Sulfur hexafluoride is primarily emitted by the electrical industry. Sulfur hexafluoride is used as a dielectric insulator in transmission lines, sub-stations, and transformers. The United States is the largest emitter of sulfur hexafluoride. The electric industry has recently begun reducing its sulfur hexafluoride emissions, however much more remains to be done.

Sulfur hexafluoride emissions can be reduced through sulfur hexafluoride recycling, leak detection and repair, and equipment refurbishment. Recycling presents the greatest opportunity for mitigation, with a net economic benefit and potential for emissions reduction of approximately 43 percent above and beyond currently planned reductions. Many companies already recycle sulfur hexafluoride. The average efficacy of their systems is 80 percent, but this could easily be increased to provide for 95 percent reductions in sulfur hexafluoride emissions. Leak detection and repair can reduce emissions that occur during operation. Finally, equipment refurbishment can also reduce emissions.

b. Magnesium production

Sulfur hexafluoride is currently used as a cover gas during magnesium production to prevent spontaneous combustion. Essentially all of the sulfur hexafluoride is emitted into the atmosphere. The International Magnesium Association, representing 80 percent of the industry, has pledged to eliminate sulfur hexafluoride by 2011. They will do so by substituting different cover gases.

Emissions can be abated by replacing sulfur hexafluoride with either sulfur dioxide or fluorinated gases. New technology has solved the toxicity, corrosion, and odor concerns associated with sulfur dioxide. Thus, it is can fully eliminate emissions that contribute to global warming, and is relatively inexpensive. The replacement of sulfur hexafluoride with fluorinated gases is also possible, although these gases still have global warming effects.

BIOGRAPHY FOR KASSIE R. SIEGEL

Kassie Siegel is Director of the Climate, Air, and Energy Program at the Center for Biological Diversity, a non-profit membership organization which c ombines conservation biology with litigation, policy advocacy, and an innovative strategic vision in working to secure a future for animals and plants hovering on the brink of extinction, for the wild areas they need to survive, and by extension for the physical, spiritual, and cultural welfare of generations to come.

Siegel is a graduate of the Boalt Hall School of Law at the University of California, and has worked for the Center for Biological Diversity since 1998. She develops and implements campaigns and strategies for the reduction of greenhouse gas pollution and the protection of wildlife threatened by global warming, and also litigates cases addressing global warming under federal and State law.

Siegel is the author of the Petition submitted by the Center for Biological Diversity in February 2005 seeking protection of the polar bear under the *Endangered Species Act,* and lead counsel of the lawsuit filed in December 2005 by the Center, Greenpeace and NRDC to compel the Bush Administration to respond to the Petition, which resulted in the January, 2007 proposal to list the polar bear as threatened under the *Endangered Species Act.* She has drafted similar petitions for other species threatened by global warming, such as twelve of the world's penguin species, including the Emperor penguin. Siegel is also a volunteer presenter for the Climate Project.

SELECTED PUBLICATIONS AND PRESENTATIONS

Cummings, B., and K. Siegel (in press). Biodiversity, Global Warming and the United States Endangered Species Act: The Role of Domestic Wildlife Law in Addressing Greenhouse Gas Emissions. In *Adjudicating Climate Control: Sub-National, National, and Supra-national Approaches* (W.C.G. Burns and H.M. Osofsky, eds.), Cambridge University Press.

Cummings, B., and K. Siegel. 2007. *Ursus maritimus:* Polar Bears on Thin Ice. *Natural Resources and Environment* 22, Number 2, Fall 2007:3–7.

Siegel, K. 'CEQA and Global Warming Matters' Private Enforcement of Environmental Law: Prosecuting and Defending Citizens' Suits, The Environmental Law Section of the State Bar of California, May 2007, Oakland, California.

Siegel, K., R. Fairbanks, and S. Sakashita 'Global Warming and Biodiversity,' 25th Annual Public Interest Environmental Law Conference, March 2007, Eugene, OR.

Siegel, K. 'Global Warming, Biodiversity, and the Endangered Species Act,' Environmental Law Conference at Yosemite, The Environmental Law Section of the State Bar of California, October 2006, Fish Camp, California.

Siegel, K. 'The No Surprises Litigation,' The Endangered Species Act Conference, CLE International, June 2004, Santa Barbara, CA.

BAR MEMBERSHIPS

- Active member of California Bar (No. 209497); admitted to practice before the California Supreme Court, the U.S. District Courts for the Northern, Southern, Central, and Eastern Districts of California, and the U.S. Court of Appeals for the Ninth Circuit.
- Inactive member of Alaska Bar (No. 0106044); admitted to practice before the Alaska Supreme Court.

DISCUSSION

RELATION OF ASTROPHYSICS TO THE ARCTIC AND POLAR BEARS

Chairman MILLER. Thank you, Ms. Siegel. I now recognize myself for an initial round of questions.

There was a Congressional Delegation, a Co-Del, of Members of this committee a couple months ago to Greenland; and I was part of the delegation, and it was striking. The scientists we talked to came from a variety of what appeared to be different disciplines that all intersected, the Arctic. They all called themselves snow and ice guys, but their disciplines were varied; and it took me a while to realize yes, that does have an intersection with research on the Arctic. Now, they also appeared to be kind of members of a fraternity. They all knew each other, knew each other's work, they'd hung out together probably in the few bars there are in Greenland, so they were familiar with each other's work.

There is a recent paper on polar bears that paints a much more optimistic picture, Ms. Siegel, or Dr. Haseltine. And one of the authors is an astrophysicist which I have got to say still does not strike me. I still do not see the intersection of astrophysics and polar bears or the Arctic, but perhaps there is one that I am missing. The paper was by Dike and Willie Soon and Willie Soon is apparently an astrophysicist. Is astrophysics one of the disciplines that has an intersection with research in the Arctic or into polar bears? Dr. Alley? Dr. Juday? Dr. Haseltine?

Dr. HASELTINE. I have to say that we have an astrophysics branch at USGS that works with NASA, and we didn't use their models in projecting polar bears.

Chairman MILLER. I took that as a delicate way of saying no, you didn't really think astrophysics had a particular application in modeling—any of the rest of you know of any work being done by astrophysicists that pertain to projections of the climate and the arctic and the effect on polar bears?

Dr. ALLEY. There has been a long interest in trying to sort out what of the changes that are occurring are natural and what of the changes occurring are human caused, and astrophysics feeds into this from one side because very clearly changes in the sun will affect the climate strongly. And there are hypotheses that are not very well validated that changes in cosmic rays or other things will matter. And so we do talk to astrophysicists on the climate end, and their output has been assessed and included in the work of the National Academy or the IPCC in saying with high confidence that the recent changes we see in the Arctic are not astrophysical, they are us.

Chairman MILLER. How about specifically the effect on polar bears?

Dr. ALLEY. I personally—normally when I get to the point of talking about biology, I get a big smile on my face and I show pretty pictures of what I have seen, but I turn to an expert.

Chairman MILLER. Okay. And I assume that all of you kind of knew each other before this? You didn't meet the first time tonight, today, is that correct? Okay. You knew of each other? Knew each other by reputation at least, even if you hadn't had beers together in a bar on the Bering Sea. Are you familiar with Dr. Willie Soon other than from the recent paper, from research in this area?

Dr. JUDAY. Yes, I try to keep up with the community in what is sometimes called the climate skeptics, and he has been prominent there. Sometimes I get good ideas of how to test some of what I think I am finding and take a more skeptical eye toward it.

Chairman MILLER. Ms. Haseltine, you look like you are ready to say something on this topic? Ms. Siegel, are you familiar with this paper and what is your take on it?

Ms. SIEGEL. I am, Mr. Chairman, and I would like to point out that the paper was funded by the Charles G. Kotch Charitable Fund, American Petroleum Institute, and ExxonMobil, and that that authors include discredited climate deniers Willie Soon, David Legates, Sally Baliunas, and others. I would also like to point out that it was published as a viewpoint in the journal *Ecological Complexity,* not as a peer-reviewed science article. This is essentially an op-ed masquerading as a peer-reviewed science journal. The article was also based on the assertion that there is no significant warming trend in Western Hudson Bay, which is simply not true. Breakup now occurs three weeks earlier in western Hudson Bay than it did 30 years ago. The sea ice is in fact declining in the Arctic. From late spring to breakup is the most important hunting time for polar bears when they eat large numbers of ringed seal pups. They now have less time on the ice to hunt. Body condition and cub survival have declined, and female polar bears that do not reach a certain minimum body weight cannot reproduce. The population has declined 22 percent from 1,200 bears in 1987 to less than 950 bears in 2004. Leading polar experts have said that suggestions that today's polar bear populations will be able to obtain food sources to replace seals caught on the ice surface is fanciful. Polar bears in western Hudson Bay during the ice-free months are in a hibernation-like state, a physiological state of fasting. They cannot replace extremely energy-intensive seal blubber with berries and opportunistic scavenging. Leading polar bear experts have stated that we must quickly and significantly reduce greenhouse gas emissions in order to save polar bears.

Chairman MILLER. Thank you. My time has now expired. Mr. Rohrabacher.

MS. SIEGEL'S BACKGROUND

Mr. ROHRABACHER. Thank you very much, Mr. Chairman. Ms. Siegel, what is your degree in, educational background?

Ms. SIEGEL. I did my undergraduate work in anthropology and economics, and I am an attorney.

Mr. ROHRABACHER. You have an undergraduate degree in?

Ms. SIEGEL. Anthropology and economics from the College of William and Mary in Williamsburg, Virginia.

Mr. ROHRABACHER. I couldn't find that in your bio here. It just states you went to Boalt Hall?

Ms. SIEGEL. Exactly, Boalt Hall at the University of California.

Mr. ROHRABACHER. Right, I know that. That is in Berkeley, is it not?

Ms. SIEGEL. That is correct.

Mr. ROHRABACHER. The Chairman quoted Mr. Hansen earlier, Dr. Hansen, and I understand that Dr. Hansen has received a substantial amount of money for his research from George Soros who is a—of course to say is politically active is to put that mildly. Has anyone else here or the organizations you are associated with or you yourself received money from Mr. Soros or his foundations to do your research or your activities? Has your organization received any money from Mr. Soros?

ARE HUMANS CAUSING CLIMATE CHANGE?

Ms. SIEGEL. Not to my knowledge.

Mr. ROHRABACHER. Not to my knowledge. Very loyal answer. There is no question obviously that the Earth is going through a warming trend right now. There is no question about that. One realizes that the Earth warming trends perhaps dozens of times, and the major question is is this warming trend caused by human activity. If it is not, should we not be looking at adapting rather than arrogantly thinking that mankind can reverse what has been a trend of nature over these many hundreds of thousands, if not millions of years of the life of the planet? Let me just say, and of course we are looking at the effects of this in terms of polar bears, et cetera. One of the reasons some of us like myself are skeptical of some of these things is just that I remember very much the predictions of dire and doom for the caribou. We ended up building a pipeline across Alaska, and I don't have to ask you, you all know, that the caribou population has drastically expanded since that pipeline, although people were testifying before Congress and just as adamant as yourselves that the caribou population was going to be decimated by the fact that there would be a pipeline across Alaska. And quite often we hear people with these dire predictions in order to whatever, accomplish perhaps other political ends. This might be more consistent with what Mr. Soros has in mind. Let me ask you this. We know the ice cores and these testings that give us an understanding of climate change in the planet, apparently Dr. Timothy Ball, who is a former climatology professor at the University of Winnipeg, stated that the theory, and I quote, in theory the claim that if CO_2 goes up, temperature will go up is wrong. The ice core record for the last 420,000 years shows exactly the opposite, that indeed increases in the temperature bring about more CO_2, rather than CO_2 increases bringing about the increase in the temperature, which of course leads directly to whether or not human kind is actually causing this increase in temperature. Now, Dr. Juday was mentioning how the methane gas is bubbling up as the temperature increases. It seems to me your testimony backed up Dr. Ball's observation, because what you were saying is that as the temperature has gone up there is more methane being put into the atmosphere. It would be wrong to say that methane increasing in the atmosphere was causing the temperature to go up, is that not correct?

Dr. ALLEY. If I were to take my credit card and overspend, I would go into debt and then I would start to make interest payments which would contribute to my debt further. If your accountant were to try to understand my debt based solely on my over expenditures, your accountant would fail. If your accountant included the interest payments that were triggered by my going into debt, your accountant would succeed. What we know very clearly is that the ice age cycles referred to by Dr. Ball are caused by features of Earth's orbit.

CLIMATE CHANGE FROM THE EARTH'S ORBIT

Mr. ROHRABACHER. By what?

Dr. ALLEY. Caused by features of Earth's orbit. Imagine that you are the sun for the moment, this is the Earth. My North Pole if it stood straight up would never get a sunburn from your brightness, but because it is inclined, I can get a sunburn on my North Pole; and the North Pole nods over 41,000 years, more sunburn, less sunburn. That plus a wobble and a change in the shape of the orbit caused the ice age. But those changes from the ice age caused changes in CO_2 and in methane, and when we try to explain the very large change in temperature on the planet for the ice ages, if we assume that CO_2 and methane do not cause warming, no one has ever explained how big the changes are in the same way that your accountant could not explain my debt without including my interest payments. If we use the warming that is expected from the CO_2 and the methane, we explain what happened. And so in exactly the same way that the interest payments on my debt contribute to my debt, it must be included to explain my debt. The interest payments of CO_2 coming up with the warming contribute to further warming and must be included to explain that warming.

Mr. ROHRABACHER. I will have to admit that I don't understand a thing that you just said——

Chairman MILLER. You can ask further in the next round of questions.

Mr. ROHRABACHER.—but I will say that you did tend to indicate that the climate change that we have seen in the past at least was caused by changes, by the sun and by changes in the Earth rather than by human activity.

Dr. ALLEY. Very clearly, the ice age cycle is not to our credit. It is nature's.

Mr. ROHRABACHER. Thank you.

EVIDENCE OF CLIMATE CHANGE

Chairman MILLER. Dr. Juday I think does want to respond. Dr. Juday?

Dr. JUDAY. Yeah, I was trying to get the point across that there are these amplification mechanisms, and the initial push can be in the short-term solar variability, volcanic eruptions of the particular kind that can cool things down and the coupled atmosphere marine circulation patterns. I have a slide that is in the post-presentation phase there where I did a test of this, and it is a long-term record. It starts in 1917, and it shows the date of ice breakup on the Tanana River in Alaska. The crews that were building the Alaska railroad got bored, and so they did a lottery and so to the minute it has been done exactly the same way ever since. And by accounting for just exactly those factors, solar variability and solar cycle, there have been El Niños and the couple of really big volcanic eruptions that we have had, take those out of that record, and they have a dramatic impact. When it is supposed to be cold, boy, we make it cold and the breakup is late; and when it is supposed to be warm, boy, they make it warm. Take them out. And what is left is a trend, and the only way to explain that trend is there is some underlying process. If you look further at the character of that process, what do you see? The daily high temperatures haven't changed all that much. The daily low temperatures have increased at the rate of three to three and one-half degrees C per century. Our growing season length has doubled. The winter temperatures have warmed.

So something is happening that is dampening heat loss, not adding extra heat during the summer.

Mr. ROHRABACHER. Doctor, the only question is whether it is human-caused or not.

Dr. JUDAY. The characteristics are exactly the characteristics of the way a greenhouse gas process works. So it matches, and if there is a better theory, I would pursue that.

Mr. ROHRABACHER. The sun.

DR. HANSEN AND GEORGE SOROS

Chairman MILLER. A couple points quickly. Dr. Hansen, I understand, denies the allegation that he has gotten money from George Soros. He is not here to defend himself. He is not a witness here today. He is a scientist at NASA. My understanding is that he is one of the world's leading climate scientists, but he has been charged with having received money from Mr. Soros, from George Soros. He says it is not true, and we have a statement from him actually in which he said that that is not true. So we will now enter that into the record.

[The prepared statement of Dr. Hansen follows:]

PREPARED STATEMENT OF DR. JAMES HANSEN

. . .And Other Forms of Lawlessness

27 SEPTEMBER 2007

The latest swift-boating (unless there is a new one among seven unanswered calls on my cell) is the whacko claim that I received $720,000.00 from George Soros. Here is the real deal, with the order of things as well as I can remember without wasting even more time digging into papers and records.

Sometime after giving a potentially provocative interview to Sixty Minutes, but before it aired, I tried to get legal advice on my rights of free speech. I made two or three attempts to contact people at Freedom Forum, who I had given permission to use a quote (something like "in my thirty-some years in the government, I have never seen anything like the present restrictions on the flow of information from scientists to the public") on their calendar. I wanted to know where I could get, preferably inexpensive, legal advice. Never got a reply.

But then I received a call from the President of the Government Accountability Project (GAP) telling me that I had won the Ridenaur Award (including a moderate amount of cash—$10,000 I believe; the award is named for the guy who exposed the Viet Nam My Lai massacre), and offering pro bono legal advice. I agreed to accept the latter (temporarily), signing something to let them represent me (which had an escape clause that I later exercised).

I started to get the feeling that there may be expectations (strings) coming with the award, and I was concerned that it may create the appearance that I had spoken out about government censorship for the sake of the $. So I called the President of GAP, asking how the nomination process worked and who made the selection. He mentioned that he either nominated or selected me. So I declined the award, but I continued to accept pro bono legal advice for a while.

The principal thing that they provided was the attached letter to NASA. This letter shows me why scientists drive 1995 Hondas and lawyers drive Mercedes. I have a feeling that the reader of that letter had at least one extra gulp of coffee that morning.

But it turns out that GAP has lost most of their cases in defending whistle-blowers. It is obviously not because they are crummy lawyers. Things are getting pretty tough in our country. It is still not clear to me what rights of free speech we actually have today.

Some people think that things must have changed in our government, since I have been speaking pretty freely of late. That is mainly appearance. The (free speech) situation in NASA is good at the moment only because our Administrator made a strong statement. The rules as written, according to GAP, will allow the next Administrator, if he so desires, to hammer the free speaker. But the big problem is that the Offices of Public Affairs in most agencies, at the Headquarters level, have been staffed with political appointees, who in effect are running Offices of Propaganda (Mark Bowen has written a book about this, which will come out in December). Public Affairs people at the field centers are dedicated professionals, but political appointees occupy the Headquarters positions in Washington. I complained about this to a Government Reform committee in the House (*littp://www.columbia.edtL/~jehl/20070319105800-43018.pdf*), saying that there should be a law that Public Affairs must be staffed by professional civil servants, not political appointees. I did not seem to raise much interest. Too much reform for a Reform committee, I guess.

The bottom line is: I did not receive one thin dime from George Soros. Perhaps GAP did, but I would be surprised if they got $720,000 (that's a lot of Mercedes). Whatever amount they got, I do not see anything wrong with it. They are a non-profit organization. Seems like a great idea to have some good lawyers trying to protect free speech.

By the way, in case anybody finds out that George Soros INTENDED to send me $720,000 but could not find my address, please let me know! We are pretty hard pressed here.

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February 8, 2006

The Honorable Dr. Michael Griffin
Administrator
National Aeronautics and Space Administration
300 E St., SW
Washington, DC, 20546

Dear Honorable Dr. Michael Griffin:

The Government Accountability Project (GAP) represents Dr. James Hansen, chief of the National Aeronautics and Space Administration's (NASA) Goddard Institute for Space Studies. We seek your commitment that Dr. Hansen will not be punished for exercising his rights under the First Amendment, Whistleblower Protection Act (WPA), and the Anti-Gag Statute to share his internationally-renowned expertise on climate change. As you may have read or heard, he has been threatened with "dire consequences" if he does not submit to blanket prior restraint on his speech. Such threats violate all three of these laws.

Your leadership would be consistent with your recent laudable email reassurances to NASA staff about scientific openness. Obviously Dr. Hansen will be the credibility litmus test that determines how other NASA scientists view these reassurances. Dr. Hansen has emphasized to us that he shares your vision for NASA and has confidence in your leadership.

We also seek your commitment to bring NASA into institutional compliance with the relevant free speech laws. We offer our organization's good offices to share relevant expertise that would be helpful. At this time we are not releasing this letter, in hopes that we might be able to work collaboratively with your office with the aim of achieving for NASA a restored and deserved reputation as an agency committed to openness and scientific freedom and integrity.

As background, in publicized speeches and papers Dr. Hansen has been sharing scientific research indicating that the "Earth's climate is nearing, but has not passed, a tipping point beyond which it will be impossible to avoid climate change with far-ranging, undesirable consequences." His disclosures have sparked a sharp response from NASA headquarters (HQ) Public Affairs Office (PAO) officials such as a Mr. George Deutsch, who reportedly explains that his job is "to make the President look good." As part of the PAO effort, Mr. Dwayne Brown has threatened Dr. Hansen with "dire consequences" unless our client refers all communications to PAO, so that others may speak for him or remain silent for him, thus in effect turning down media interviews for no apparent or appropriate reason.

PAO has drafted a policy of blanket prior restraint to institutionalize Dr. Hansen's treatment. The policy would cover all NASA scientists, civil servants and government-paid contractors. To summarize, it would require that *all* communications from the media go through PAO; *no* comments or interviews may occur without advance permission; and that higher management officials have a "right of first refusal" (PAO's words) to substitute for NASA's career scientists responding to *all* interview requests.

Neither Mr. Brown's threats nor the PAO policy can coexist with the United States Constitution. It is beyond any credible debate that the First Amendment protects Americans from having to get prior permission to exercise free speech rights. Our nation long has prided itself that we do not have an Official Secrets Act.

These actions also would directly violate two specific laws passed by Congress to implement constitutional free speech rights: the Whistleblower Protection Act (WPA) of 1989, 5 USC 1101 et seq., and the Anti-Gag Statute, found in section 620 of the Transportation, Treasury and Independent Agencies Appropriation Act of 2005. These are fundamental laws with an impressive mandate; for example, the Anti-Gag Statute has passed congress with unanimous bi-partisan consensus each year for 17 years. The popularity of these laws is understandable. As the sponsors explained in floor speeches, the WPA more accurately should be called the Taxpayer Protection Act. The stakes are particularly high if a gag order silences employees from even protesting censorship. They are higher still when the secrecy suppresses scientific findings relevant for understanding climate change – a most serious threat to citizens of every nation.

It is the Government Accountability Project's mission to monitor these laws. We are a non-profit, non-partisan organization whose mission is to represent and otherwise support "whistleblowers," employees who exercise free speech rights to challenge abuses of power that betray the public trust. Those two laws are the twin pillars of legal rights for government whistleblowers. We led multi-year efforts of good government coalitions to earn passage of both laws. While we hope to work with your office constructively, we have no intention of passively acquiescing if they are defied. And Dr. Hansen will not be silenced.

Of course, agencies have the right to insist that their employees speak with one voice when describing official policy. That does not mean, however, that they lose their rights as free citizens by working for the government. *Pickering v. Board of Education*, 368 U.S. 415 (1968).

The Whistleblower Protection Act shields public disclosures that employees reasonably believe are evidence of illegality, gross waste, gross mismanagement, abuse of authority, or a substantial and specific danger to public health or safety. The only exceptions are if information is classified, or if its release is specifically prohibited by statute. In 5 USC 2302(b)(8), the WPA outlaws "threatened" retaliation the same as actual harassment, because like all other prior restraint it proactively suppresses the flow of information. Mr. Brown's pending threat of "dire consequences" constitutes a violation per se. Even your helpful email communication will not overcome the deep chill that Mr. Brown and other Public Affairs officials have spawned.

The Anti-Gag Statute bans spending to implement or enforce agency nondisclosure rules that seek to trump the whistleblower law or the Lloyd Lafollette Act of 1912, 5 USC 7211. The latter protects all communications with Congress. Indeed, any lawful nondisclosure rule must include a specific qualifier preserving free speech rights under those and related good government laws, as follows:

No funds appropriated in this or any other Act may be used to implement or enforce the agreements in Standard Forms 312 and 4414 of the Government or any other nondisclosure policy, form, or agreement if such policy, form, or agreement does not contain the following provisions: 'These restrictions are consistent with and do not supersede, conflict with, or otherwise alter the employee obligations, rights, or liabilities created by Executive Order No. 12958; section 7211 of title 5, United States Code (governing disclosures to Congress); section 1034 of title 10, United States Code, as amended by the Military Whistleblower Protection Act (governing disclosure to Congress by members of the military); section 2302(b)(8) of title 5, United States Code, as amended by the Whistleblower Protection Act (governing disclosures of illegality, waste, fraud, abuse or public health or safety threats); the Intelligence Identities Protection Act of 1982 (50 U.S.C. 421 et seq.) (governing disclosures that could expose confidential Government agents); and the statutes which protect against disclosure that may compromise the national security, including sections 641, 793, 794, 798, and 952 of title 18, United States Code, and section 4(b) of the Subversive Activities Act of 1950 (50 U.S.C. 783(b)). The definitions, requirements, obligations, rights, sanctions, and liabilities created by said Executive order and listed statutes are incorporated into this agreement and are controlling.'

There is personal liability for repayment under the Anti-Deficit Act for officials responsible for violating the spending ban.

Both by setting a positive example through outreach and reassurance to Dr. Hansen and revamping your agency's press policy, you can bring NASA into compliance with these two fundamental good government statutes. We will gladly work cooperatively with your staff on this matter, a far less burdensome option than conflict challenging WPA violations that have occurred already, as a minimum. It is all the more detrimental for the taxpayers when the government violates the laws designed to protect those challenging government censorship or other forms of lawlessness. Our organization will contact your office to see if we may be of assistance.

Sincerely,

Thomas Devine
Legal Director

Louis Clark
President
Counsel for Dr. James Hansen

cc: NASA Headquarters

SCIENTISTS NAMED STEVE

Chairman MILLER. I have a peculiar question that may take you a while to think about because we all know people named Steve. It may take us a second to think of who they are. One of the frustrations of dealing with what scientists think is that there are so many scientists. But there is a science blog called Panda's Thumb that has done kind of a canvas of the scientists named Steve. I thought that that was a more workable number of people. And when there is a dispute about what scientists think, rather than try to canvas all scientists, they try to canvas the scientists named

Steve, an intriguing idea and one that probably makes statistical sense. It is probably a statistically valid sample. Do you know of any climate skeptics who believe that either the globe's climate is not changing, it is not warming, or that the cause is not human activity named Steve? You can get back to us on that.

Dr. ALLEY. I am finding one right now.

Chairman MILLER. How about scientists named Steve? Can you think of scientists named Steve who believe that the world's climate is changing and it is warming and it is resulting in human activity, named Steve? Dr. Allen?

Dr. ALLEY. Steven Schneider Stanford would be a good starting point.

Chairman MILLER. Okay. Dr. Juday, any Steves come to your mind?

Dr. JUDAY. Yeah, there is one I thought of.

Chairman MILLER. Okay. Dr. Haseltine.

Dr. HASELTINE. I would say Steve Amstrup who is our lead polar bear biologist in Alaska and experiences conditions in the Arctic out in the field every year.

Chairman MILLER. Okay.

Dr. HASELTINE. He certainly believes the climate is changing.

PROCESSES LEADING TO THE TIPPING POINT

Chairman MILLER. So it is two to nothing among Steves that you can think of. Okay. But you all can think of other Steves and get back to this on what the Steves you know, the scientists named Steve, think. Dr. Alley, I understand that the IPCC probably had some difficulty of kind of projecting exactly what the processes were that would lead to the cascading effect, the tipping point that you talked about. How well are they accounted for, and particularly the ones we talked about today, the melting of the permafrost, the release of carbon dioxide and methane from the permafrost. How much was that considered in the IPCC modeling?

Dr. ALLEY. It is not well included in the IPCC modeling. In fact, there is a statement in regard to the sea level rise that because of lack of inclusion of these carbon cycle feedbacks, which is what you are referring to, and because of lack of inclusion of understanding about the changes in the flow of the ice sheets, that they can provide neither a best estimate nor an upper limit on what sea level will do, and those were the two uncertainties that were especially highlighted.

Chairman MILLER. Anyone else? That seemed to be a question for Dr. Alley or anyone else. Congratulations by the way on winning the Nobel Prize.

Dr. JUDAY. Mr. Chairman, I think to squeeze the last bit of uncertainty out of that question, we have one more piece of information that we need, which is we need to poke holes in the tundra and see if there is charcoal in them because the fact that we are seeing fires now, and it is warmer now and that makes it flammable doesn't quite rule out the possibility that it happened before. It is not reported, it is not known, everybody that I have spoken to who works in—charcoal, base of the tundra? No, no, no. But we have to do that work in order to be absolutely confident that this isn't already dialed into the system that we have now.

Chairman MILLER. Well, I will actually set an example and not use the last 18 seconds of my time. Mr. Rohrabacher?

Mr. ROHRABACHER. Thank you. I don't know if he ever signed his name Steve but I certainly know numerous other scientists who don't believe in the global warming that we are experiencing today as human-caused. I also note there is a scientist named Patrick Michaels who was the former Chairman of the Committee of Applied Climatology of the American Meteorological Society who suggests that all these reports of the melting of all the ice on Greenland are totally exaggerated. I have a quote here from——

Dr. JUDAY. Congressman, if I can just clarify what I intended my response to be, all of the factors that can produce warming or cooling happen all at the same time, and all I was saying is that you have to account for all of them. It is a good thing when you are trying to quantify one to isolate it and see what strength its effect is, but then don't make the mistake of going back and saying, oh, the others don't happen. They all happen at the same time.

POLAR BEAR POPULATION CHANGES IN CANADA

Mr. ROHRABACHER. All I can suggest is there are a lot of people who, a lot of very, very well-known scientists, respected scientists throughout the world, people especially at the senior levels who are—that they believe that their fellow scientists have been influenced by the desire to get government grants for funding and the fact that since Bill Clinton became President of the United States, the bill all those years back, that in order to get those grants you had to believe global warming was caused by human beings. I have a statement here, several here, of scientists, Dr. Mitch Taylor, a polar bear biologist in the government there in Canada, and he is suggesting that the polar bear population is not going down. In fact, in 13 populations of polar bears in Canada, 11 are stable or increasing in number, another quote suggesting the polar bear numbers were actually underestimated in prior years and thus now in fact are not seeing this decrease as it is being suggested today. Are these two scientists just off or——

Dr. HASELTINE. I could respond to that. I believe the 13 populations that you see quoted there are the 13 that at least have some of their territory in Canada. That is the number in Canada, and in the reassessment that we did over the last year, five of those populations are declining, two of them are depressed from over hunting, several of them are stable, I don't remember the exact number, and none of them are demonstrating to be increasing. So that is the——

Mr. ROHRABACHER. So Dr. Taylor, the head of this department there whose job it is to keep track of this, this isn't just a side desk, this is what his job is, is wrong and you are right?

Dr. HASELTINE. Well, I am quoting from the results of the study in a recent article by——

Mr. ROHRABACHER. Which is a study by the Geological Survey?

Dr. HASELTINE. Right, and a recent article by Ian Sterling who is one of the senior polar bear researchers for the Canadian Wildlife Service. And so I think this individual who works with Nunavut territories in Canada——

Mr. ROHRABACHER. Okay, well——

Dr. HASELTINE.—is using older information.

NATURALLY OCCURRING CLIMATE CHANGE

Mr. ROHRABACHER. Well, let me put it this way. There are experts who are not named Steve who are disagreeing with what the findings are of the people here today. Let us just note this that again, the central issue is whether or not all of these things are caused by human activity or not. Just coincidentally two nights ago the History Channel again ran, with updates quite often, its long documentary on the mini-ice age; and one of the facts I noticed there what they presented which is again showing how 1,000 years ago it was a lot warmer up in Greenland and Iceland and these places, a lot warmer than it is today. And in fact, I don't know what the polar bear population was at that time, and I am not sure that is not the natural number of polar bears we should have in the world as compared to now, but they did note that they said the volcanic activity during the mini-ice age was about five times greater than it has been over the last 150 years and that volcanic activity which they then went into with their scientists on the History Channel were indicating that volcanic activity actually creates a situation where the Earth would be warmer without that volcanic activity because it reflects the rays of the sun.

So here we have only one degree or maybe one and one-half degrees warmer over the 150 years since the end of the mini-ice age, and we have five times less the volcanic activity which would tend to make it a warmer situation, not to mention sunspots or whatever else; there is a natural explanation for this as compared to the fact that we are driving in SUVs or we have industrialization which of course can in no way explain the warming that is also going on on Mars and Jupiter. So why is it that we should be so concerned and try to regulate human activity to save the polar bears when all of this may be just a natural occurrence?

Chairman MILLER. I was relieved to hear the word why, suggesting that there was actually a question there. We are now over the time, but you could respond briefly.

Dr. JUDAY. I was lead author of a chapter of Arctic climate impact assessment in which we reviewed the evidence based on tree ring studies that gives us essentially a complete record from 8,000 years, and it shows the ups and downs of the climate; and I would just refer you to that if you would like to go through what has happened when, and I believe you can download it at *www.acia.uaf.edu.* You have brought up several different ideas there, and I just offer to talk to you to help untangle some of them and distinguish between two things, the empirical fact of what has happened and the interpretations of why, the attribution.

Dr. ALLEY. Just to add, as you know, scientists float all kinds of wonderful ideas and smart ones and crazy ones and we bubble with ideas and then you help pay for activities that seek to assess these and to give you sort of what stands solidly and what is not solid, and those activities often come out of the National Academy of Sciences, they come out of the Intergovernmental Panel on Climate Change. Those groups have assessed these. They have looked at the effect of volcanoes, the effect of sun, the effect of other things and come to high scientific confidence that in fact you see our footprint now in what is going on. I would also like to add, and you were quoting a scientist earlier, suggesting that perhaps we are twirking our research to gain government grants and that we might not be completely honest in what we are doing? Sir, personally, I am under oath and I would never, ever, ever do that and I do not believe any of my colleagues would do that. Rest yourself absolutely assured that we are trying our hardest and we are not lying to you, sir.

Mr. ROHRABACHER. I will submit for the record at this point then several quotations from very respected scientists making that suggestion of others and who——

Dr. ALLEY. I am under oath.

Mr. ROHRABACHER.—skewed research, et cetera, et cetera, in order to get government grants. I will be happy to submit those for the record.

[The information follows:]

SUBMITTED FOR THE RECORD
BY REPRESENTATIVE DANA ROHRABACHER

QUOTES FROM EMINENT SCIENTISTS ON SEVERAL GLOBAL WARMING ISSUES

Undue pressure and influence related to funding as well as political peer pressure

William Gray

Bio

Dr. William M. Gray is a world famous hurricane expert and emeritus Professor of Atmospheric Science, Colorado State University

Quote From an article in *Discover,* Vol. 26 no. 9, September 2005

"So many people have a vested interest in this global-warming thing—all these big labs and research and stuff. **The idea is to frighten the public, to get money to study it more."**

See *http://discovermagazine.com/2005/sep/discover-dialogue/*

"Researchers pound the global warming drum because they know there is politics, and money behind it."

Richard Lindzen

Bio

Dr. Richard Lindzen is an atmospheric physicist, the Alfred P. Sloan Professor of Meteorology at MIT and a member of the National Academy of Science Lindzen is known for his research in dynamic meteorology—especially atmospheric waves.

Quote From a *Wall Street Journal* op ed April 12, 2006; Page A14

"Alarm rather than genuine scientific curiosity, it appears, is essential to maintaining funding. And **only the most senior scientists today can** stand up against this alarmist gale, and **defy the iron triangle of climate scientists, advocates and policy-makers."**

See http://www.opinionjournal.com/extra/?id=110008220

Quote From *Environment News,* November 1, 2004 Publisher: The Heartland Institute

"Global warming debate is more politics than science"

Dr. William Happer Jr.

Bio

Dr. Happer was named Eugene Higgins Professor of Physics and Chair of the University Research Board and is a Fellow of the American Physical Society, the American Association for the Advancement of Science, and a member of the American Academy of Arts and Sciences, the National Academy of Sciences and the American Philosophical Society.

Quote

When Director of Energy Research at the U.S. Department of Energy for two years, Happer was asked to leave. **"I was told that science was not going to intrude on policy."**

"With regard to global climate issues, we are experiencing politically correct science. **Many atmospheric scientists are afraid for their funding, which is why they don't challenge Al Gore and his colleagues.** They have a pretty clear idea of what the answer they're supposed to get is. The attitude in the administration is, **'If you get a wrong result, we don't want to hear about it.'"**

See *http://www.sepp.org/Archive/controv/controversies/happer.html*

Dr. Petr Chylek

Bio

Dr. Petr Chylek is a member of the technical staff at Space and Remote Sensing Sciences, Los Alamos National Laboratory and an Adjunct Professor of Physics and Atmospheric Science, Dalhousie University, Halifax and New Mexico State University.

Quote

"Scientists who want to attract attention to themselves, **who want to attract great funding to themselves, have to (find a) way to scare the public**. . .and this you can achieve only by making things bigger and more dangerous than they really are."

See *http://www.sepp.org/Archive/weekwas/2001/Aug25.htm*

Dr. Bjorn Lomborg

Bio

Dr. Lomborg is adjunct professor at the Copenhagen Business School, and author of the best-selling "The Skeptical Environmentalist." *He organized the "Copenhagen Consensus" which brought together some of the world's top economists.*

Quote

"Its fear-mongering arguments have been sensationalized, which is ultimately only likely to make the world worse off."

See *http://www.opinionjournal.com/extra/?id=110009182*

Cost of Mitigatiion

Patrick Michaels

Bio

Dr. Patrick Michaels is a senior fellow at the Cato Institute and a Research Professor of environmental sciences at the University of Virginia. He is a Past President of the American Association of State Climatologists and was Program Chair for the Committee on Applied Climatology of the American Meteorological Society.

Quote from an article "Live With Climate Change" in *USA Today* on February 2, 2007

"The stark reality is that **if we really want to alter the warming trajectory** of the planet significantly, **we have to cut emissions by an extremely large amount,** and—a truth that everyone must know—**we simply do not have the technology to do so.** We **would fritter away billions** in precious investment capital in a futile attempt to curtail warming"

See *http://www.cato.org/pub_display.php?pub_id=7502*

Sea Level Change

Patrick Michaels

Bio

Dr. Patrick Michaels is a senior fellow at the Cato Institute and a Research Professor of environmental sciences at the University of Virginia. He is a Past President of the American Association of State Climatologists and was Program Chair for the Committee on Applied Climatology of the American Meteorological Society.

Quote from an article "Global Warming: So What Else Is New?" in the *San Francisco Chronicle* on February 2nd, 2007.

"As measured recently by satellite, and published in *Science* magazine, **Greenland is losing .0004 percent of its ice per year, or 0.4 percent per century.** All modern computer models require nearly **1,000 years** of carbon concentrations three times what they are today **to melt the majority of Greenland's ice.** Does anyone seriously believe we will be a fossil-fuel powered society in, say, the year 2500?"

"A small but very vocal band of **extremists have been hawking a doomsday scenario,** in which Greenland suddenly melts, raising sea levels 12 feet or more by 2100." ". . .it is repeated everywhere, and its supporters are already claiming that the **IPCC**" . . . **"is now wrong because it has toned down its projections of doom and gloom."** See *www.cato.org/pubdisplay.php?pub_id=7543*

Decline of Polar Bear Population

Dr. Mitchell Taylor

Bio

Dr. Mitchell Taylor, Polar Bear Biologist, Department of the Environment, Government of Nunavut, Igloolik, Nunavut

Quote

"Of 13 populations of polar bears in Canada, 11 are stable or increasing in number. They are not going extinct, or even appear to be affected at present,"

See *http://ff.org/centers/csspp/library/co2weekly/20060505/20060505_17.html*

IPCC Climate Models

Fred Singer

Bio

Dr Fred Singer is an atmospheric physicist and Professor Emeritus of Environmental Sciences at the University of Virginia, adjunct scholar at the National Center for Policy Analysis, and former Director of the U.S. Weather Satellite Service.

Quote

"The models have erroneously predicted a 20th century surge in the Earth's temperatures to match surging $CO_2$2 concentrations in the atmosphere. It hasn't happened."

See *http://potpourriessays.blogspot.com/2007/06/global-warming.html*

Richard Lindzen

Bio

Richard Lindzen is an atmospheric physicist, the Alfred P. Sloan Professor of Meteorology at MIT and a member of the National Academy of Science Lindzen is known for his research in dynamic meteorology—especially atmospheric waves.

Quote from the *Sunday Telegraph,* October 30 2006

"As the primary "consensus" document, the Scientific Assessment of the UN's Intergovernmental Panel on Climate Change notes, **modelers at the United Kingdom's Hadley Centre had to cancel two-thirds of the model warming in order to simulate the observed warming.**

"So the warming alarm is based on models that **overestimate the observed warming by a factor of three or more,** and have to cancel most of the warming in order to match observations.

"The temperature is as likely to go down as up."

http://www.telegraph.co.uk/news/main.jhtml?xml=/news/2006/10/29/nclimate129.xml

Kevin Trenberth

Bio

Dr. Kevin E. Trenberth is Head of the Climate Analysis Section at the National Center for Atmospheric Research. He has published over 400 scientific articles or papers, including 40 books or book chapters.

Quote

None of the models used by IPCC are initialized to the observed state and none of the climate states in the models correspond even remotely to the current observed climate. In particular, the state of the oceans, sea ice, and soil moisture has no relationship to the observed state at any recent time in any of the IPCC models.

See *http://blogs.nature.com/climatefeedback/2007/06/predictions_of_climate.html*

Reducing Methane Emissions

Chairman MILLER. Please do that, and Mr. Rohrabacher, you have promised to provide that list on several occasions for the record, and we have not gotten it at previous hearings, but we will certainly be happy to take that.

It now appears that George Soros and ExxonMobil may be in a desperate competition to identify a scientist named Steve whose research they can fund. Ms. Siegel, it is true that you are not a scientist on this panel. You are a lawyer, but it appears that your testimony was the most hopeful of the testimony that we have heard today. The three scientists were less hopeful or their presentations were more grim than yours, but I do have a couple questions about what we can be doing which is part of your testimony as well. There is a landfill in my district. There are landfills in everybody's district, but in this one, it is being closed up, it is being covered over, and they are still pulling off the methane and piping it a mile or two away to a manufacturer who then uses that methane and burns it for energy. What is it that governments and corporations and individuals can be doing and are doing that would significantly reduce methane?

Ms. SIEGEL. Thank you, Mr. Chairman. As you mentioned, we have enormous opportunities to reduce methane from the waste, the agriculture, and the energy sectors. One of the most important things we can do in the waste sector is to divert organic materials from landfills through composting, recycling, and reuse programs. Where that is not feasible, methane can be captured from the landfill gas and used to generate electricity. The U.S. EPA estimates that 88 percent or 110 million metric tons could be abated this way in this country by 2010, and 10 percent or 12 million metric tons could be abated at a cost benefit or no cost.

We can also capture methane from wastewater treatment plants and use it to generate electricity. The biggest opportunities are in the developing world where EPA estimates there are approximately 600 million metric tons of CO_2, equivalent methane emissions reductions sitting on the table. We don't have cost estimates for this, but it is clear that expanding wastewater treatment facilities in the developing world will have enormous public health benefits for disease prevention and greatly reduce methane emissions.

In the energy sector, we also have enormous opportunities. One of the primary sources of methane from natural gas systems is through the leakage from lines and equipment, and there are many, many different measures that fall into three categories including operational changes, equipment upgrade and replacement, and better inspection and maintenance; and over 50 percent of methane emissions, or 76 million metric tons, could be abated this way with technology available today. 14.5 percent or 20 million metric tons could be done at a cost benefit of up to $25 per metric ton from the natural gas sector. Methane is also released from coal mining because methane is produced when organic matter turns to coal and is present in coal seams. We need an immediate moratorium on new coal-fired power plants and to ultimately phase out existing plants, and therefore coal mining as well; but nevertheless, it is foolish to allow methane emissions to continue where coal mining is still carried out for the time being. Nearly 50 percent or 25 million metric tons of baseline emissions could be eliminated by the year 2010 in the U.S. at a cost benefit or no cost. About 86 percent could be eliminated for less than $15 per ton.

Also, in the agricultural sector, we have very important opportunities to capture methane from manure lagoons rather than just letting the manure sit in the lagoons and emit the methane using something called methane digesters. A digester is a system of containers to collect and biologically treat manure with naturally occurring microorganisms. The methane can then also be used to generate electricity.

The EPA conservatively estimates that 11 million metric tons of CO_2 equivalent cost beneficial or no-cost emissions could be abated this way from the agricultural sector.

Action Items to Reduce Emissions

Chairman Miller. Thank you. One other question about along the lines of action items, things that we can actually do. You mentioned black carbon and the role that black carbon plays in global warming. According to a recent NASA study, I assume it was a NASA study and not a George Soros study, it could have been by Dr. Hansen, black carbon which is really just particulate matter or soot. I think you used the word soot actually from industrial and biomass sources, is having a significant warming impact in the Arctic because it reduces the reflectivity of snow and ice. And according to NASA, about a one-third of the black carbon in the arctic was actually coming from South Asia and one-third from burning biomass or vegetation around the world and one-third from North America, Russian, and Europe. What can be done to reduce those sources and is it happening? Is anyone doing it?

Ms. SIEGEL. The origin of black carbon that is deposited in the Arctic is a very important area for further research, but it is clear that the U.S. has a leadership role to play in this regard. There are many, many things that can be done. For example, we can replace diesel generators in the Arctic with alternative energy sources, and where that is not possible improve the efficiency and particulate controls on these generators. We can replace coal and biomass burning in residential stoves with alternative fuels or improve the efficiency in particulate traps. Stringently regulating diesel use in cars and trucks is very, very important and options include upgrading vehicles, installing end-of-pipe filters, better vehicle maintenance, and buyout/buyback programs for super-emitters. We also need to not approve new coal-fired power plants, phase out of existing coal-fired power plants by increasing energy efficiency in the use of alternative energy, and where coal-fired power plants must continue to operate for now, implement more effective particulate controls. If we did all these things we could start seeing progress by January 2009.

Chairman MILLER. Thank you, Ms. Siegel. Mr. Rohrabacher.

POLAR BEAR POPULATIONS 1,000 YEARS AGO

Mr. ROHRABACHER. Thank you very much. I am just surprised that my staff had not submitted the quotes before, but we will be submitting these quotes for the record. One of them I just happen to have with me right now is from a Dr. William Grey who is one of the world's most respected hurricane experts and Emeritus Professor of Atmospheric Science at Colorado State University who suggests that so many people have a vested interest in this global warming thing, all these big labs and research. The idea is to frighten the public to get money to study it more. That is the end of that quote. And there are about dozens of other quotes that we will put at least five or six of them in the record. Dr. Grey is a respected person. There are many, many respected scientists who are skeptical not of the idea that the Earth is going through a warming trend but that this has something to do with human activity. Again, the show that I just happened to see on the History Channel, which repeated and it is a wonderful documentary, went into great detail about the sun and about volcanic activity and those things that caused the temperature to change then. Let me ask you this, 1,000 years ago before this mini-ice age, before this trend that brought the temperatures down, which I might add, all the studies that I have seen on global warming start at the bottom of the mini-ice age after 500 years reduction of temperature using that as the baseline, and you are one and one-half degrees warmer than it was at the lowest point, as if we should be concerned about that. Let us go back to that, the 1,000 before. How many polar bears were there 1,000 years ago when the temperature was much different than it is today?

Dr. HASELTINE. I don't think we know the number of polar bears at that time. We do know that polar bears existed back then.

Mr. ROHRABACHER. If we say they can't exist if it is going to be warmer now, we could assume there are fewer polar bears. Now, is the number of polar bears 1,000 years ago what would be the natural polar bear population or is it what it is now?

Dr. HASELTINE. I don't believe there is a natural number of polar bears. There will be a number of polar bears that their habitat can support.

CLIMATE CHANGE SINCE THE LAST ICE AGE

Mr. ROHRABACHER. I think it is wonderful to see these pictures of the skinny polar bear up there and tearing at our hearts, those of us who love animals, and I do; and so you say, then we have to do something which then gives us the right to have the acceptance of our people to regulate their lives in the name of saving that polar bear who now is thin as if we are causing the polar bear to be thin. But in reality, 1,000 years ago before any human activity had anything to do with temperatures on the planet, even if you accept that 1,000 years ago, the polar bear population was totally different. It was warmer. Maybe you could tell me what was the ice cap like or what was the level of ice in Greenland 1,000 years ago?

Dr. ALLEY. Our observations are not as good as we would like, and we are working on that. The Climate Change Science Program is going to do a report on that, and I am one of the authors. So to be very clear, I cannot either prejudge or presize what that report will say.

Mr. ROHRABACHER. Well, what was Greenland like and what——

Dr. ALLEY. What we can say is that Greenland seems to have responded to temperature. When it was warmer, it got smaller, when it was colder it got bigger and that we are now pushing toward temperatures that will pass those of the medieval warm, that will pass those of the——

Mr. ROHRABACHER. Well, no, no, we are one and one-half degrees warmer now than it was 150 years ago and we have so much less volcanic activity, et cetera. And it was how many degrees warmer was it 1,000 years ago?

Dr. ALLEY. There are places—we do not have——

Mr. ROHRABACHER. In Greenland and Iceland?

Dr. ALLEY. We do not have a reliable global—probably a degree or two, something in that neighborhood.

Mr. ROHRABACHER. What do the ice cores show us?

Dr. ALLEY. The ice cores show a very small signal that is about one degree, one and one-half degrees or something in that neighborhood in the summit of Greenland which is the one I worked on——

Mr. ROHRABACHER. How much——

Dr. ALLEY.—and that is based on my work.

Mr. ROHRABACHER. How much warmer was it when they had all these Vikings and everybody living in Greenland and Iceland and they have all this agriculture going on? How much warmer was it then? I think the History Channel put it at eight degrees to 10 degrees warmer.

Dr. ALLEY. That would seem very large to me. Ice core records would indicate that we are back up to where we were if not passing it.

Dr. JUDAY. Yeah, that is probably the case. I, by the way, did a story, was interviewed, by a reporter from the *Wall Street Journal* and—farmer in Greenland. So we are back to about where we were 1,000 years ago. It is my suggestion if you want to find that warmer period to use, I would suggesting the hosing thermal maximum, the warmest it got since the end of the last ice age, and that would be in the range of 6,000 to 8,000 years ago. It was warmer than it is now. It has been cooling since——

Mr. ROHRABACHER. All right, so 8,000 years ago there was a period with almost no ice up there, and we think that today——

Dr. JUDAY. No, the tree line was further north. You can find frozen remains of the trees almost to——

Mr. ROHRABACHER. All right. So it was dramatically warmer 1,000 years ago and 8,000 years ago.

Dr. JUDAY. We are probably warmer now than 1,000 years ago. We probably exceeded that.

CLIMATE CHANGE FROM CARBON METHANE IN THE PERMAFROST

Chairman MILLER. We are past time. We do have votes coming up, so we do need to conclude the hearing. I just have one more question for Dr. Alley. You said that the permafrost and frozen peat, the possibility of release of carbon methane in the permafrost and frozen peat was a big hole in the modeling by the IPCC of how our climate could change and how our climate could warm, but you didn't say how much. Do you have a sense of how big the effect of that can be?

Dr. ALLEY. What it looks like based on simple models based on what we know is that it doesn't—if we humans burn all of our fossil fuel, the feedbacks from the permafrost do not double what we did, but they are large enough that they wouldn't matter to what we would do.

Chairman MILLER. Large enough didn't matter?

Dr. ALLEY. Yeah, so we scientists like to say order of when we are a little bit confused, so order of 10 to 30 percent sort of feedbacks coming out of this, amplifying what we would do in a burn it all.

Dr. JUDAY. If you could take all of the rapidly decomposable carbon, because some of it is locked away in a form, and it is just not going to come out, but so that is killing everything and burning up everything, it would double—it is equal to the atmospheric reservoir. So it would double atmospheric CO_2, so we are not going to do that, even under the worst scenarios, but it does look like a significant percentage of non-renewable percentage of it could and probably has started to be mobilized.

Chairman MILLER. Anyone else? Okay. I think that our hearing is at a close. I want to thank all of you for testifying today. There may be additional questions that could be submitted in writing. You may think more about the scientist you know named Steve and provide additional answers. And with that, the witnesses are excused, and the hearing is now adjourned.

[Whereupon, at 11:43 a.m., the Subcommittee was adjourned.]